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February 1975

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Office of Research and Development
U.S. Environmental Protection Agency
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February 1975

ENVIRONMENTAL BASE AND MANAGEMENT STUDY

ATCHAFALAYA BASIN, LOUISIANA

By

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Contract No. 68-01-1845
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FOREWORD

The Atchafalaya Basin is a large semiwilderness area of national significance lying within the State of Louisiana. While the primary use of the Basin is and must remain as a floodway, there are innumerable other land uses and natural resources within the floodway. The natural swamp-like environment of the Basin dictates that land use management be controlled by the availability and quality of the water. Optimum use of the Basin, therefore, requires an effective water management plan that is based on an understanding of water needs to sustain or improve present ecosystems, and on consideration of effects caused by different types of land use. In concept, such a plan must recognize environmental opportunities and constraints while, at the same time, allowing man to make adaptations of the environment necessary for his successful use of its resources.

In 1972 at the request of the Governor of Louisiana and in response to a Senate committee resolution, the U.S. Environmental Protection Agency (EPA) joined in an interagency study with the State of Louisiana, U.S. Army Corps of Engineers, and the U.S. Department of the Interior in a land and water management study of the Atchafalaya Basin. As part of this effort, EPA chaired a work group charged with developing management alternatives for the Basin.

This report develops an approach to water management in the Basin that is compatible with the use of the Basin as a floodway while optimizing the protection of renewable resources. The objective of protecting natural values is shown not to be inconsistent with the use of the Basin as a floodway. Further, consideration is given to navigation needs and to other present and projected uses. These efforts have led to proposed conceptual guidelines for overall management of surface water appropriate for consideration in connection with the proposed enlargement of the Atchafalaya River Channel and the Lower Atchafalaya River and Bayous Chene, Boeuf, and Black Navigation Projects.

While additional approaches to water management need to and will be developed for the Atchafalaya Basin, this study represents a first step. As a next step, the environmental impacts of this and other approaches need to be thoroughly analyzed before any management plan is adopted.

This study was conducted by the Center for Wetland Resources, Coastal Resources Unit, Louisiana State University, Baton Rouge, Louisiana 70803. The work was supported by the Ecological Impact Analysis Staff, Washington Environmental Research Center.

Edwin B Royce

Edwin B. Royce, Acting Director
Ecological Impact Analysis Staff

ABSTRACT

The present report attempts to develop an alternative water management scheme for the Atchafalaya Basin. In the development of this scheme, the Basin is viewed as a product of the interaction between physical, chemical, biological and human systems. This allowed the division of the area into environmental management units within which environmental conditions and processes and human use are similar. Recognizing the overriding need to use the Basin as a floodway, the options for water resource management were further evaluated through an analysis of trends in the Basin environment resulting from either natural processes or human impact related to various uses. Much emphasis is placed on the requirements for management of overflow swamp areas, which form the most productive biological resource of the Basin. Most essential to this type of environment is an annual influx of water from the adjacent stream channels through overbank flooding, unimpeded movement of inflowing water through the swamp, and drainage from the lower end. The major threats to the overflow swamp environment are the present influx of sediment, insufficient overbank flooding, and insufficient interior circulation.

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The help of the Atchafalaya Basin Commission and Mrs. Sandra Thompson, Director of the Atchafalaya Basin Division of the Louisiana Department of Public Works has been of considerable value.

Without the cooperation of the Basin Planning Division and the Hydrology Branch of the New Orlean District, U.S. Corps of Army Engineers, the study would not have been possible, as much of the basic hydrologic and sediment data from the study area has been collected by the Corps.

Discussions with personnel of the Louisiana Wild Life and Fisheries Commission have provided us with an insight into requirements for fisheries and wildlife management. Mr. Ken Lantz and Mr. Jack Collins have been particularly helpful in this regard.

A review of the literature by Dr. Carl Bond pertaining to life cycles and environmental requirements of crustaceans and fin fish found in the Basin has been invaluable. His insight into the requirements of these animals as communicated to us during the course of field trips and conferences represents a valuable contribution.

Mayor C. R. Brownell of Morgan City, Louisiana and Mr. Fielding Lewis, representative of the St. Mary Parish Police Jury, provided important insight into the flood management and environmental problems of the lower and middle Atchafalaya River Basin.

The study was made in collaboration with Alice R. Franklin, Philip Light, Penny Culley, Robert Wilson, and Karen Wicker. Cartography was done by Curtis Latiolais, and editing by Peggy King.

SECTION I

CONCLUSIONS

1. A major diversion of the Mississippi River occurring during historic times has transformed the study area from a predominantly wetland environment dominated by in situ processes to one that becomes increasingly terrestrial, where riverine processes now play a major role.

2. The freshwater, transported sediment, and dissolved solids of the Atchafalaya River represent a tremendous source of energy and materials that can be applied toward environmental management. The value of this resource has previously been underestimated. Management for environmental enhancement has been virtually nonexistent.

3. Since about 1950 the locus of active sedimentation has shifted from the middle basin, an area of lacustrine delta building, to the lower basin, where a marine delta is forming.

4. During the period 1940 through 1969, there has been a 10 percent loss in aquatic and wetland habitats (approximately 90 mi^2) within the floodway.

5. The Upper Belle River Management Unit represents the last essentially unmodified overflow swamp in the basin. If no management is initiated, the swamp will be significantly modified within 35 years.

6. The dredging of cross navigation channels has, in at least one case, greatly contributed to excessive siltation in the lower floodway.

7. Trends of environmental succession indicate that only through management can high productivity from the fisheries standpoint be maintained.

8. An approach has been developed for establishing required water levels and circulation for individual management units.

9. It is feasible to maintain or enhance the viability of overflow swamps in the basin through manipulation of water levels and circulation.

10. In each management unit it is possible to maintain any desired water level with water derived from local runoff only.

11. The ideal configuration for an overflow swamp is a pan-shaped depression, separated from the flanking river channels by a rim that only allows inflow during high stages, and having a shallow drainage network with one or more outlets at the lower end of the depression.

12. Lake Fausse Pointe and Lake Verret-Palourde isolated swamps are particularly vulnerable to influx and concentration of pollutants from adjacent agricultural areas.

13. Implementation of currently proposed flood control and navigation projects within the study area is considered undesirable in view of perpetual siltation problems causing serious environmental damage and requiring extensive maintenance dredging and spoil disposal; this is in contrast to the opinion of the Corps of Engineers by whom the authorized flood control project is considered to be a practicable plan to minimize siltation.

SECTION II

RECOMMENDATIONS

1. The natural basin has been altered to such an extent that, at the highest level, management should deal with segments or units of what formerly constituted an integrated natural system.

2. Management in various parts of the basin should be based on process-form relationships that are presently dominant, and management units should be defined to represent areas where present land use and environmental conditions are similar.

3. In many cases dredging and spoil deposition have resulted in excess siltation and reduction of overflow and throughflow. Dredging, in reference to the mineral industry, usually represents a conflict with preferred management practices. To reduce the detrimental impact, geometry of canal networks should be planned in reference to long term environmental management objectives, as well as immediate objectives of recovery of subsurface minerals.

4. Alternatives should be considered for accommodating navigation interests without diverting large amounts of sediment through cross navigation channels.

5. To prevent further deterioration of the Buffalo Cove and Upper Belle River units and to maintain the option for their management as fish-productive overflow swamps, corrective measures concerning sediment influx should be taken without delay.

6. Water level data should be collected in overflow swamp areas to determine the relationship between swamp levels and stages in adjacent river channels.

7. In regard to the proposed Center Channel, stage characteristics should be determined for various Center Channel discharges to determine how present management options would be affected.

8. The channel geometry that can be expected to satisfy equilibrium conditions for average annual maximum and minimum discharges should also be determined in order to evaluate the possibility of extensive maintenance dredging and spoil disposal.

9. In view of the imminent development of a marine delta in Atchafalaya Bay, high priority should be given to determine land ownership and to develop management guidelines for this deltaic area.

10. In order to reduce siltation in the middle basin and reduce maintenance dredging in navigation channels, the present flood

control and navigation proposal should be modified. An alternative approach is presented in this report.

11. It is recommended that the presented alternative approach be further evaluated and developed into a practicable plan through integration of human and biological requirements and hydrologic characteristics of the study area.

SECTION III

INTRODUCTION

Description

The Atchafalaya Basin is a large, shallow depression lying within the deltaic plain of the Mississippi River in south Louisiana. It comprises an 1800 mi^2 lowland area confined between natural levee ridges that delineate present and former courses of the Mississippi River (Fig. 1-1). Until about 90 years ago it was occupied by a series of large freshwater lakes and extensive swamps. At that time, a major upstream diversion of the Mississippi River was initiated, and floodwaters and sediment from the Red River and the Mississippi began to enter the basin, initiating major changes in the configuration and environments of the basin.

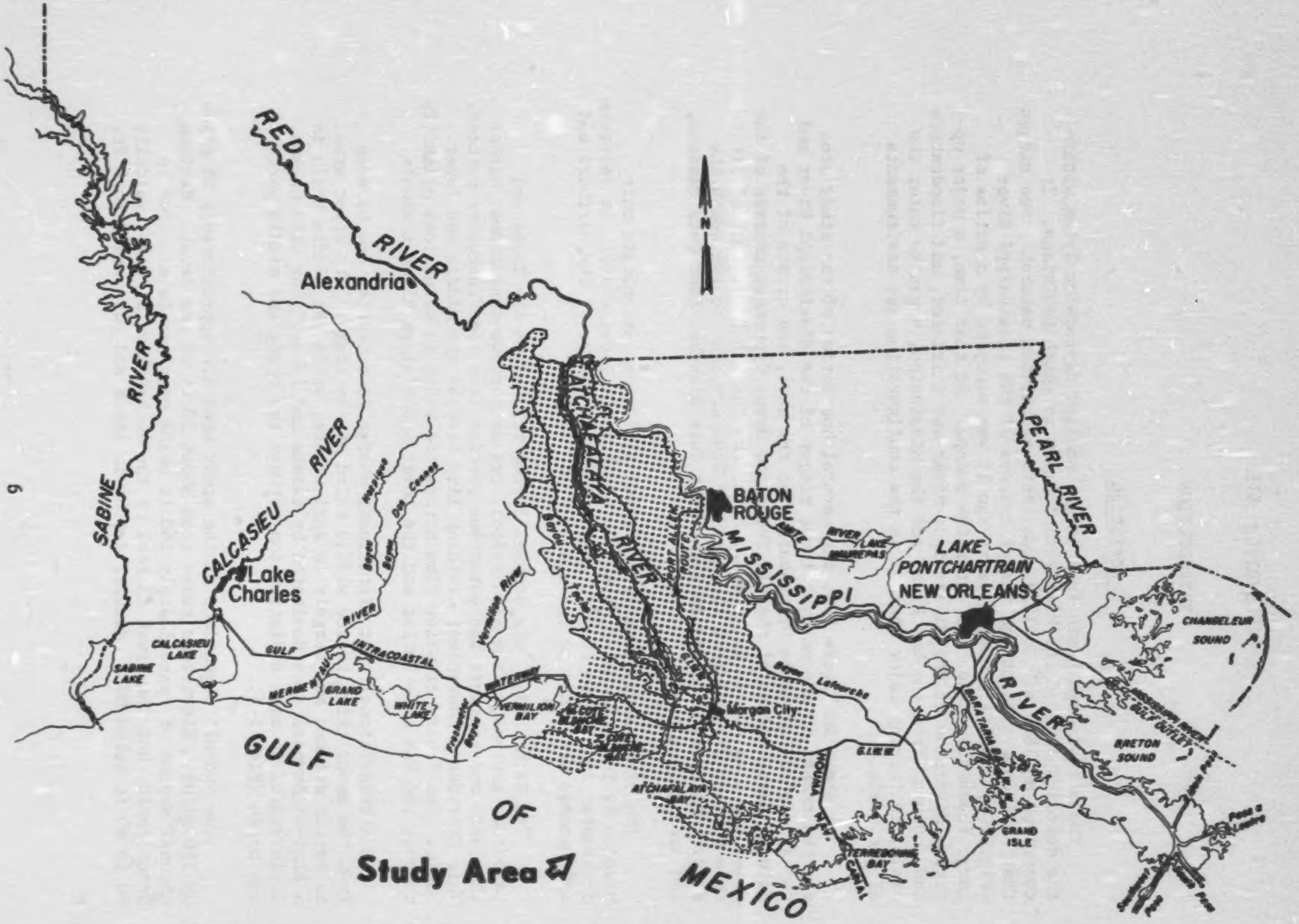
As shown in Figure 1-2, the natural boundaries of the study area are the crests of the natural levee ridges of the Mississippi River and the abandoned Lafourche Distributary on the east, and crests of the natural levee ridges of the old Teche and Bayou Cypremort courses of the Mississippi on the west. The Red River and the Old River Control Structure Outflow Channel form the Northern boundary, and to the south the study area opens into and includes West Cote Blanche, East Cote Blanche, and Atchafalaya Bays.

The study area constitutes, then, a distinct hydrologic unit, bounded by low alluvial ridges. In addition to local runoff, it receives freshwater input from the Red and Mississippi Rivers at the northern end and becomes estuarine to the south.

The Teche Ridge, old natural levees related to the Teche and Lafourche courses of the Mississippi, trends northwest-southeast across the basin and segments the estuarine portion from the freshwater portion. This provides a convenient dividing line between the middle and lower basin. Continuity of water flow across the ridge is maintained primarily through the Wax Lake Outlet and the Lower Atchafalaya River channels.

A transitional, but significant change in character can be seen from the upper third to the middle third of the basin. The upper area is better drained and largely in agriculture, while the middle basin is a semi-wilderness area dominated by swamps and lakes. For this reason, it is useful to make a distinction between the upper and middle parts of the basin (Fig. 1-2).

The overall dimensions of the study area are approximately 45 miles by 120 miles. Elevations range from about 50 ft to sea level. Maximum channel depths of approximately 160 ft below mean sea level occur in scour pools, but the trunk channel of the Atchafalaya is more typically 40 to 80 ft below MGL. Natural depths in lakes and bays are 2 to 8 ft.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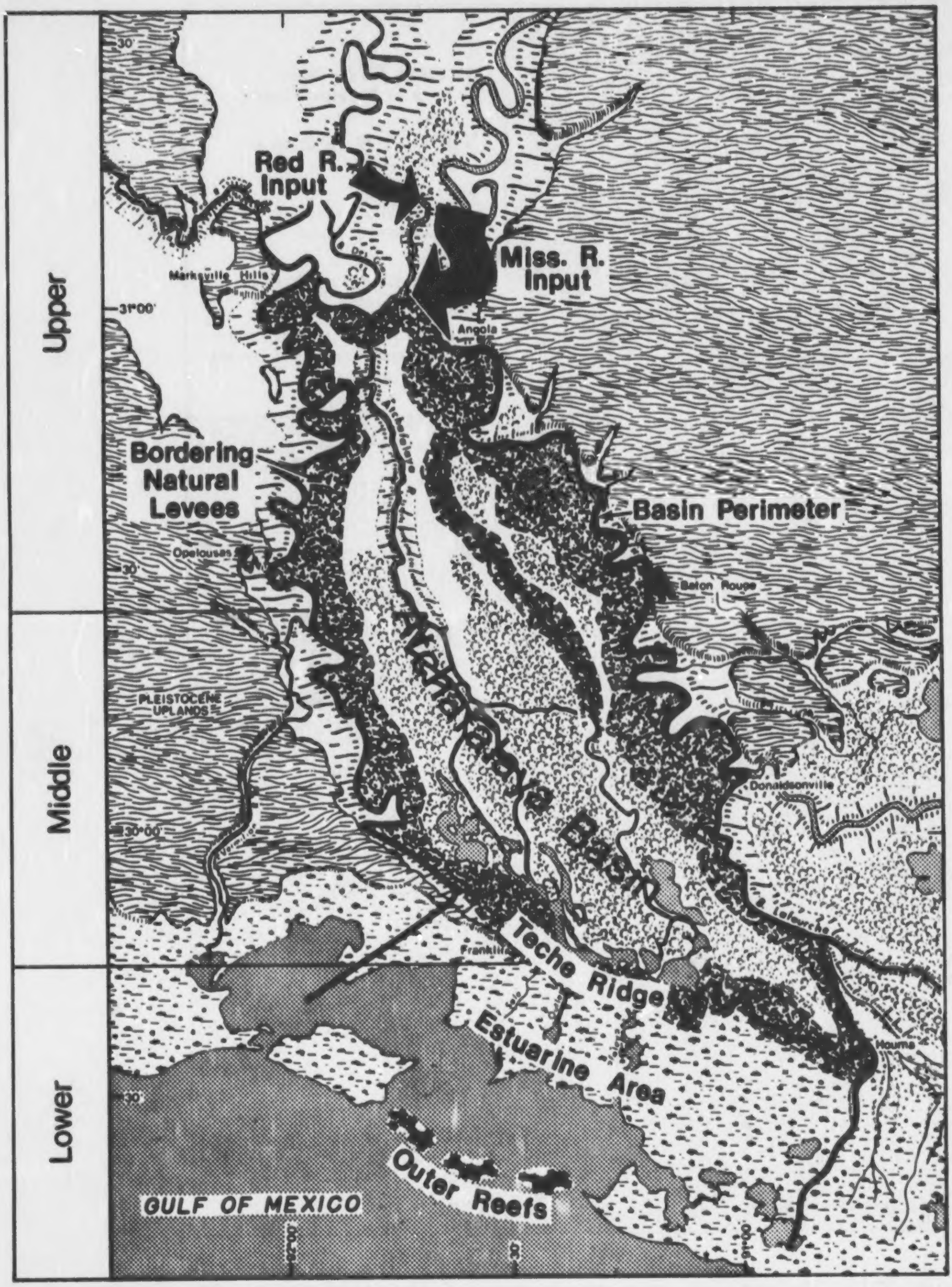
Alexandria
SABINE RIVER
CALCASIEU RIVER
Lake Charles
SABINE LAKE
CALCASIEU LAKE
GULF INTRACOASTAL WATERWAY
MERMENTAU RIVER
GRAND LAKE
WHITE LAKE
VERMILION BAY
ATCHAFALAYA RIVER
ATCHAFALAYA BAY
BATON ROUGE
MISSISSIPPI RIVER
Morgan City
Bayou Lafourche
G.I.W.W.
HOUMA NAV. CANAL
TERREBONNE BAY
GRAND ISLE
BARATARIA BAY
LAKE PONTCHARTRAIN
LAKE MAUREPAS
NEW ORLEANS
PEARL RIVER
CHANDELEUR SOUND
BRETON SOUND
MISSISSIPPI RIVER GULF OUTLET
N
GULF OF MEXICO
Study Area

Figure 1-1. Atchafalaya study area and its relationship to the Louisiana coastal zone.


Upper
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Angola
Bordering Natural Levees
Basin Perimeter
Opelousas
30'
Baton Rouge
PLEISTOCENE UPLANDS
Atchafalaya Basin
Donaldsonville
30°00'
Franklin
Teche Ridge
Estuarine Area
Houma
30'
Outer Reefs
GULF OF MEXICO
92°00'
30'

Figure 1-2. Boundaries and salient features of the Atchafalaya study area.

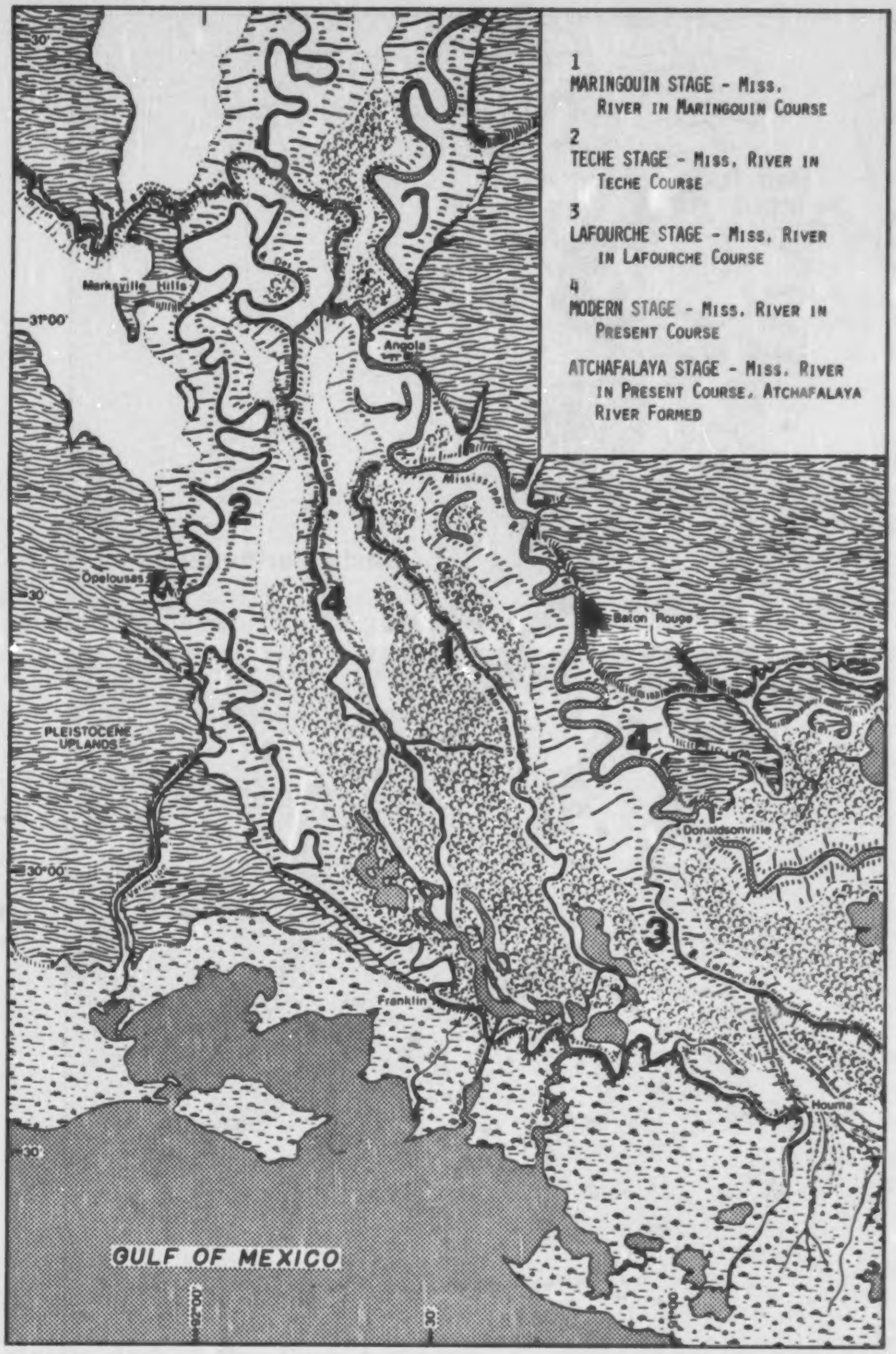
1
MARINGOUIN STAGE - MISS. RIVER IN MARINGOUIN COURSE
2
TECHE STAGE - MISS. RIVER IN TECHE COURSE
3
LAFOURCHE STAGE - MISS. RIVER IN LAFOURCHE COURSE
4
MODERN STAGE - MISS. RIVER IN PRESENT COURSE
ATCHAFALAYA STAGE - MISS. RIVER IN PRESENT COURSE, ATCHAFALAYA RIVER FORMED
30'
Marksville Hills
31°00'
Angola
2
Opelousas
30'
Baton Rouge
4
1
PLEISTOCENE UPLANDS
4
Donaldsonville
30°00'
3
Franklin
Houma
30'
GULF OF MEXICO
92°00'
30'

Figure 1-3. Modern and ancient courses of the Mississippi River in the study area (after Fisk, 1952).[1]

---

[1] H. N. Fisk, *Geological Investigation of the Atchafalaya Basin and the Problem of Mississippi River Diversion* (U.S. Army Corps of Engineers, Vicksburg, Miss., 1952).

The configuration of the natural basin is the product of a long history of delta building. The bounding alluvial ridges are natural levees formed by overbank flooding along active and abandoned courses of the Mississippi (Fig. 1-3). Levees along the present Mississippi and most of those along the Teche are related to mature meander belts formed along the trunk channel of the river. In these instances, the river maintains a relatively stable course for periods of 100 years or more. During this period, meandering and aggradation produce a broad and thick belt of river-deposited sediment and a distinctive ridge system. The Bayou Teche course of the Mississippi was active from 4000-6000 years ago, and the present course of the river was initiated over 1000 years ago (Frazier, 1967).[2]

The Maringouin Ridge (Fig. 1-3) is related to a very old course of the Mississippi, active from 6000-7000 years ago at a time when sea level was at a lower stand than at present. Most surface expression of features related to this old course has been subsequently drowned by sediment, and only the crest of the ridge remains as testimony to these past events.

Levees along Bayou Lafourche and Bayou du Large were formed along distributaries of the Lafourche Delta complex and are less than 2000 years old. A number of smaller natural levee ridges within the basin attest to positions of former crevasse distributaries.

As previously mentioned, prior to the historic diversion of the Mississippi and Red Rivers into the Atchafalaya area, the basin was occupied by extensive swamps and lakes. Both geological and archeological evidence suggest that these types of environments dominated the area for thousands of years. Study of continuous undisturbed borings indicates that the upper 100 ft of sedimentary deposits consist predominantly of clays and peats deposited in lacustrine and swamp conditions (Coleman, 1966;[3] Krinitzsky and Smith, 1969).[4] Channel and levee sands, silts, and clays are associated with the meander belts and distributaries previously mentioned, but most of the area has been occupied by swamps and lakes for thousands of years.

Prehistoric Indian sites in the form of shell middens or refuse heaps, mounds, and camp areas have been found in and around the basin.

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[2] D. E. Frazier, Recent Deltaic Deposits of the Mississippi River; Their Development and Chronology, (Gulf Coast Association, Geol. Soc. Trans., V. 17), pp. 287-315.

[3] James M. Coleman, Recent Coastal Sedimentation: Central Louisiana Coast, (Coastal Studies Institute Report L.S.U., December 1, 1966).

[4] E. L. Krinitzsky and F. L. Smith, Geology of Backswamp Deposits in the Atchafalaya Basin, Louisiana. (U. S. Army Corps of Engineers, Waterways Experiment Station, Technical Report S69-8, 1969).

Within the basin proper these are located primarily on old natural levee ridges and lakeshores (McIntire, 1958[5],1959).[6] Prominent in a number of sites are the shells of fresh and brackish water clams (Unio sp. and Rangia cuneata, respectively). These clams abounded in the lakes in the basin. Preferred locations for major village sites were on crevasse distributaries. The crevasse channels provided access to the basin environments, as well as a link to the major river systems, which were arteries of transportation. Contents of the middens indicate that the Indians harvested finfish and shellfish, small game, reptiles, waterfowl, and plant materials from the rich environments of the basin for at least 2,000 years. Archeological evidence indicates that the area has been occupied for at least 12,000 years, but economies of the earlier inhabitants are not as well known (Gagliano, 1967,[7] 1970;[8] Gibson, 1970).[9]

Before the diversion, freshwater input consisted entirely of local runoff plus some overbank flooding from the Mississippi. Periodically, a crevasse distributary found its way into the basin interior and may have constructed a small lacustrine delta. This accounts for the distinctive lake to swamp sequence so prominant in the cores taken through deposits of the basin. An intricate network of interior drainage streams was well adjusted to local runoff and flooding. Extensive pure stands of cypress-tupelo gum swamp found in historic times indicate advance stages of vegetation succession and hydrologic regimes that were relatively stable for long periods of time. From the standpoint of natural processes and environmental change, then, the basin was in a rather static or balanced condition prior to the diversion and was dominated by *in situ* processes.

Mississippi and Red River Diversion into the Atchafalaya Area

River systems have a habit of branching and developing distributaries in their deltaic areas. One type of branching occurs near the mouth of the river or in places where it enters a large depression and the trunk channel loses its identity. At such places, loss of velocity and transport capacity results in rapid deposition of bed load causing build up of bars and shoals. Thus, the river's sediment blocks the channel mouth and causes it to split or branch. This type of branching, called bifurcation, is characteristic of lacustrine and marine deltas.

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[5] W. G. McIntire, *Prehistoric Indian Settlements of the Changing Mississippi River Delta* (La. St. Univ. Press, Coastal Studies Series No. 1, 1958), 127 pp.

[6] W. G. McIntire, *Methods of Correlating Cultural Remains with Stages of Coastal Development* (La. St. Univ., C.S.I., 2nd Coastal Geography Congress, 1959), pp. 341-359.

[7] Sherwood M. Gagliano, *Occupation Sequence at Avery Island* (Coastal Studies Series No. 22, Louisiana St. Univ. Press, Baton Rouge, 1967), 109 pp.

[8] Sherwood M. Gagliano, *Archeological & Geological Studies at Avery Island* (1968-1970: Progress Report, Center for Wetland Resources, L.S.U., Baton Rouge, La., 1970), 21 pp.

[9] Jon Gibson, *Paleo-Indian Era in Louisiana* (Louisiana Heritage, Alexandria, Vol. 2, No. 3, 1970), pp. 18-19.

Another type of branching, which may eventually result in complete abandonment of a delta complex, is that of upstream diversion. This process causes major shifts of the trunk channel and usually takes place many miles from the coast in the upper deltaic plain or alluvial valley.

The primary cause of upstream diversion is gradient advantage. There are many paths from the alluvial valley to the Gulf that are considerably shorter and steeper than the present sinuous course of the Mississippi. A careful evaluation of the geologic and historic data pertaining to Mississippi River diversions led Fisk (1952, p. 105)[10] to the conclusion that even though there are shorter routes that the river might take, it will divert only after "development of an advantageously situated distributary so that it becomes enlarged and can accept the full flow of the Mississippi River." Fisk noted further that "the process of diversion begins when the river fortuitously intersects a minor alluvial valley stream." This usually occurs through lateral migration of the trunk channel. From time to time, a meander loop may intersect independent streams draining the basin areas. Even after such an intersection is made, the diversion usually requires about 100 years for completion (Fisk, 1952).[11]

As the diversion progresses, both the new course and the old one undergo a sequence of changes or adjustments. Fisk has identified four stages in the evolution of the diversion:

Initial Stage. The new channel is too small and crooked to accommodate all of the Mississippi water offered at its upper end; widespread overbank flooding occurs along its course. As the new channel enters lakes and swamps, it has a tendency to divide or braid, and many small, shallow channels develop. Natural levees start to form, and low stage flow may help enlarge the channel.

Intermediate Stage. Flow is mainly concentrated in the channel, but periodic overbank flooding builds higher natural levees along the upper reaches of the diversion. These help concentrate flow, causing increased scour and a gradual increase in the capacity of the channel. Flow and sediment load increase from flood to flood.

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[10] H. N. Fisk, 1952, op. cit.

[11] Ibid.

Critical Stage. This condition is reached when there is essentially a balance in flow between the old and the new channels. Since the new channel has the gradient advantage, it continues to enlarge at the expense of the old channel. As the old channel begins to die, it gradually closes in the reaches just below the point of diversion.

Final Stage. The old channel is plugged with sediment near the point of diversion. The sediment plug in the channel is a consequence of diminishing velocity and sediment-carrying capacity. The lower reaches of the channel gradually fill with finer sediment introduced during floods.

A major diversion of the Mississippi from its present course to one through the Atchafalaya Basin has been in progress since early historic times (Fig. 1-4). If control structures near the diversion point had not been constructed by the U. S. Army Corps of Engineers (completed in 1963), it is likely that the Atchafalaya diversion would now be in the critical stage.

Until 1881, the Atchafalaya Basin, although indirectly connected with the Mississippi, was blocked by a raft. However, after this raft was cleared, the Atchafalaya began to enlarge, and the diversion process was underway. Flow increase down the Atchafalaya for the period 1882-1960 is given in Table 1-1.

Of particular importance to this discussion is the fact that prior to the diversion, the Atchafalaya Basin was occupied by a network of sluggish streams, extensive swamps and marshes, and a series of large lakes (Fig. 1-5). Since the diversion started, a large part of this lowland has been filled by overbank flooding and lacustrine delta building. As illustrated in Figures 1-5 through 1-9, a bead-shaped series of large lakes (Lake Fausse Point, Grand Lake, Six Mile Lake, and Flat Lake) has been systematically filled by river sediment during the last 5 or 6 decades as the Atchafalaya has built a large lacustrine delta through the depressions. During this interval, these lakes have acted as a settling basin or trap and have retained most of the sediment transported by the river system.

However, the basins have now largely become filled. Since about 1950, a marine delta has started to build in Atchafalaya Bay and each year since that time, an increasing proportion of the total transported sediment load of the river system has passed through the Lower Atchafalaya and Wax Lake Outlet channels into the lower basin.

Periodic sampling of sediment by the U.S.C.E. beginning in January, 1964, indicates a yearly rate of 13 million yd^3 per year entering Wax Lake Outlet, and 36 million yd^3 per year entering the

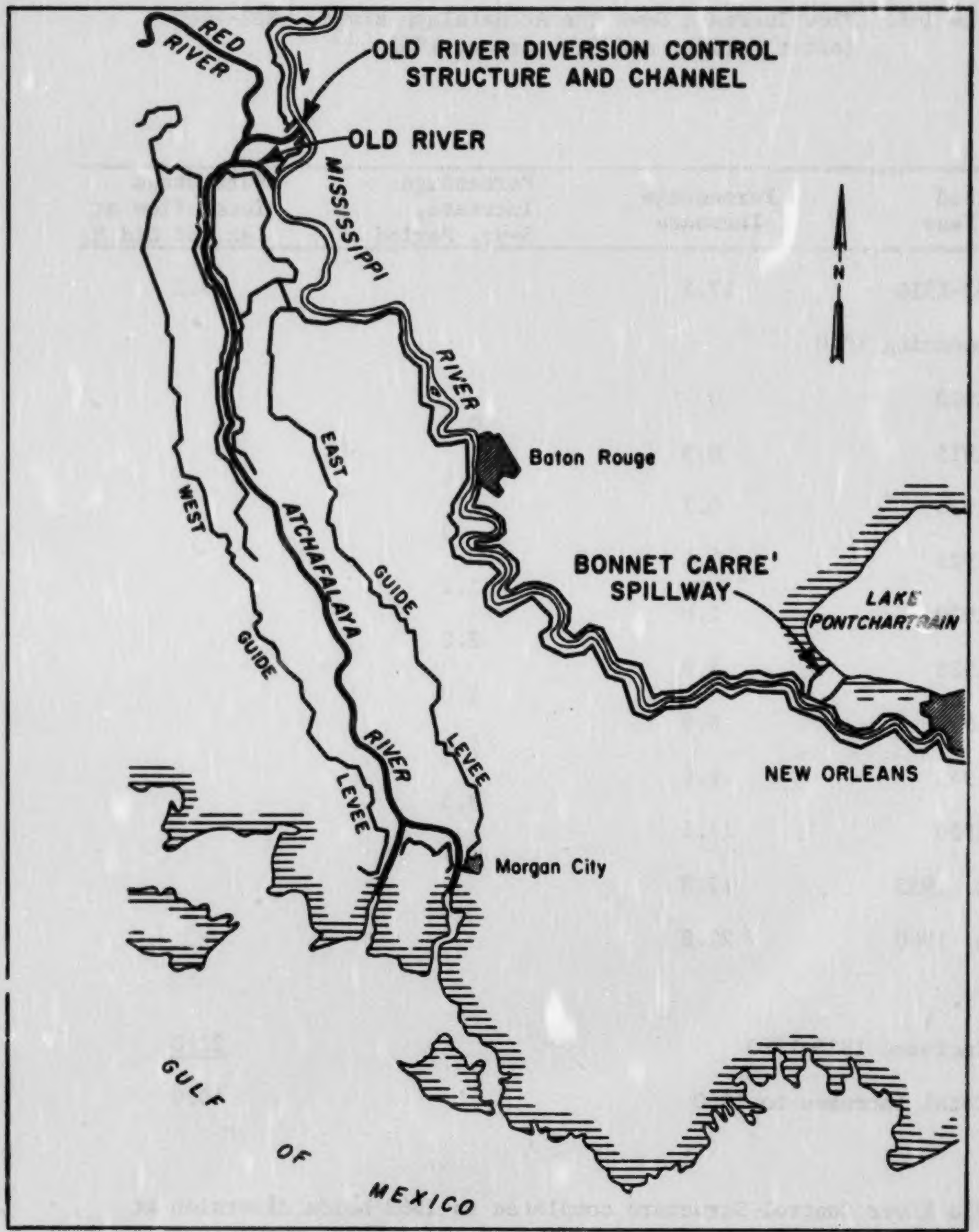
RED RIVER
OLD RIVER DIVERSION CONTROL STRUCTURE AND CHANNEL
OLD RIVER
MISSISSIPPI
RIVER
N
Baton Rouge
EAST
GUIDE
LEVEE
WEST
GUIDE
LEVEE
ATCHAFALAYA
RIVER
BONNET CARRE' SPILLWAY
LAKE PONTCHARTRAIN
NEW ORLEANS
Morgan City
GULF
OF
MEXICO

Figure 1-4. **Map showing Atchafalaya River diversion channel and related control structures (after Price, 1965).**[12]

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[12] G. A. Price, Jr., Sediment Diversions Through Distributary Channels Normal to a Major River (U. S. Dept. of Agr-. Misc. Pub. 970, 1965), pp. 185-193.

Table 1-1. Flow Increase Down the Atchafalaya River, 1882-1960 (after Latimer and Schweitzer, 1951).[13]

Period or Year	Percentage Increase	Percentage Increase, 5-yr. Period	Percentage Total Flow at Lat. of Old R.
1882-1910	17.2		17.2
Commencing 1910			
1910	0		
		0.3	
1915	0.3		
		0.4	
1920	0.7		
		.9	
1925	1.6		
		1.2	
1930	2.8		
		2.0	
1935	4.8		
		2.0	
1940	6.8		
		2.8	
1945	9.6		
		3.5	
1950	13.1		
		4.7	
Est. 1955	17.8		
		5.0	
Est. 1960	22.8		
Increase 1910-1960			22.8
Total Increase to 1960			40.0

Old River Control Structure completed in 1963 holds diversion at approximately 30 percent of latitude flow.

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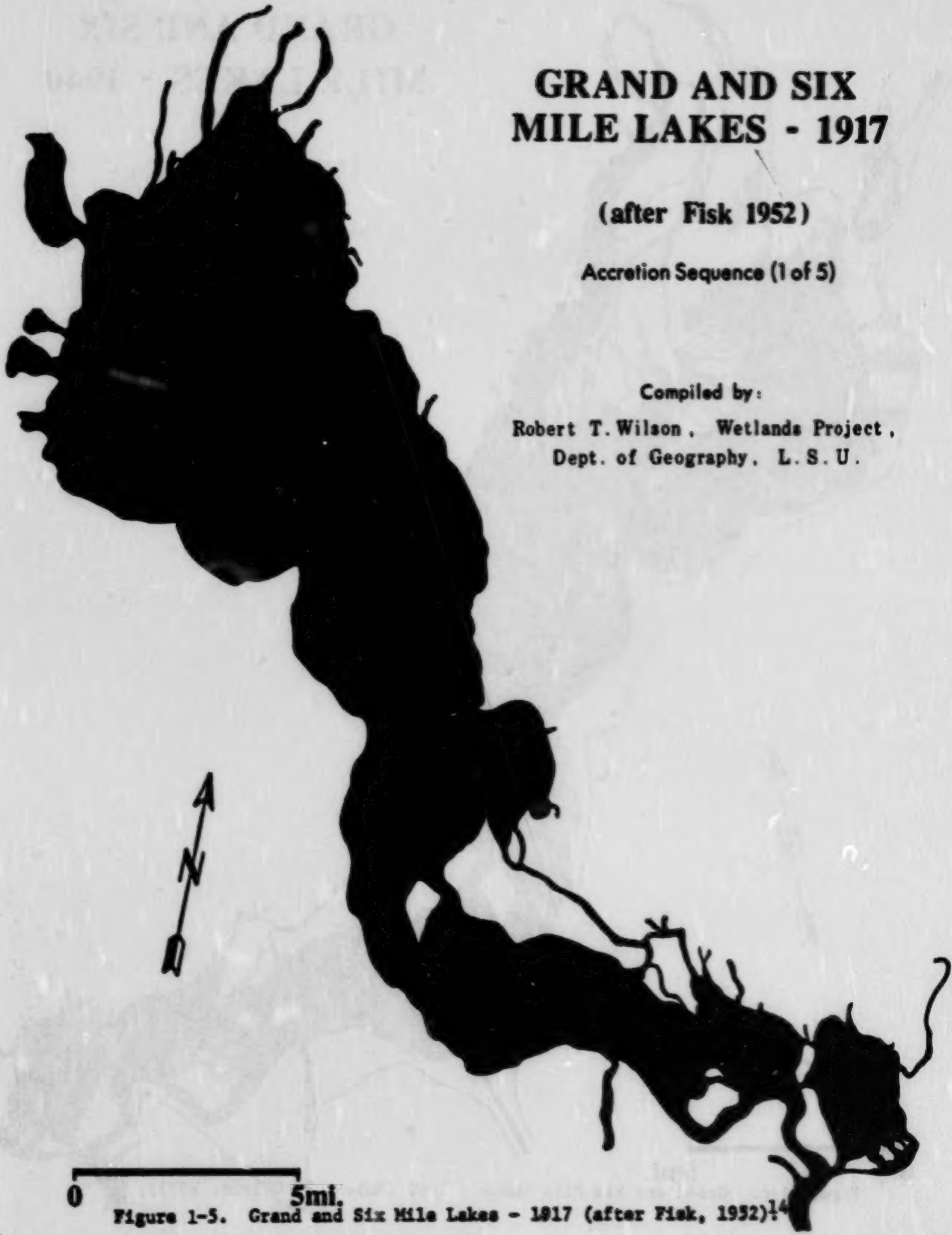
[13] R. A. Latimer, and C. W. Schweizer, *The Atchafalaya River Study: A Report Based Upon Engineering and Geological Studies of the Enlargement of Old and Atchafalaya Rivers* (3 vols, U. S. Army Corps of Engineers, 1951).



GRAND AND SIX
MILE LAKES - 1917

(after Fisk 1952)

Accretion Sequence (1 of 5)

Compiled by:
Robert T. Wilson, Wetlands Project,
Dept. of Geography, L. S. U.

Figure 1-5. Grand and Six Mile Lakes - 1917 (after Fisk, 1952).[14]

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[14] H. N. Fisk, 1952, *op. cit.*

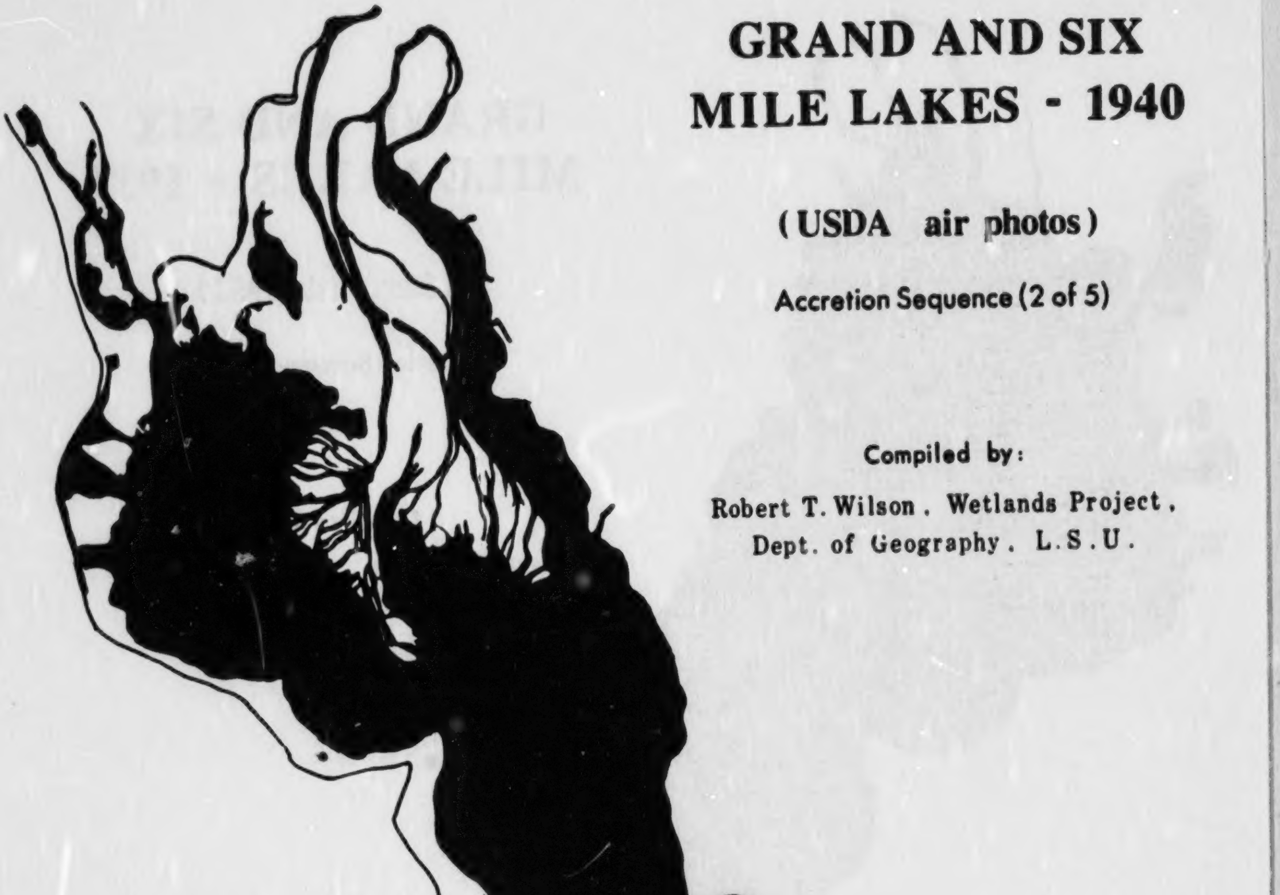
GRAND AND SIX MILE LAKES - 1940
(USDA air photos)
Accretion Sequence (2 of 5)
Compiled by:
Robert T. Wilson, Wetlands Project,
Dept. of Geography, L.S.U.
N
0
5mi.

Figure 1-6. Grand and Six Mile Lakes - 1940 (Robert T. Wilson, 1973).

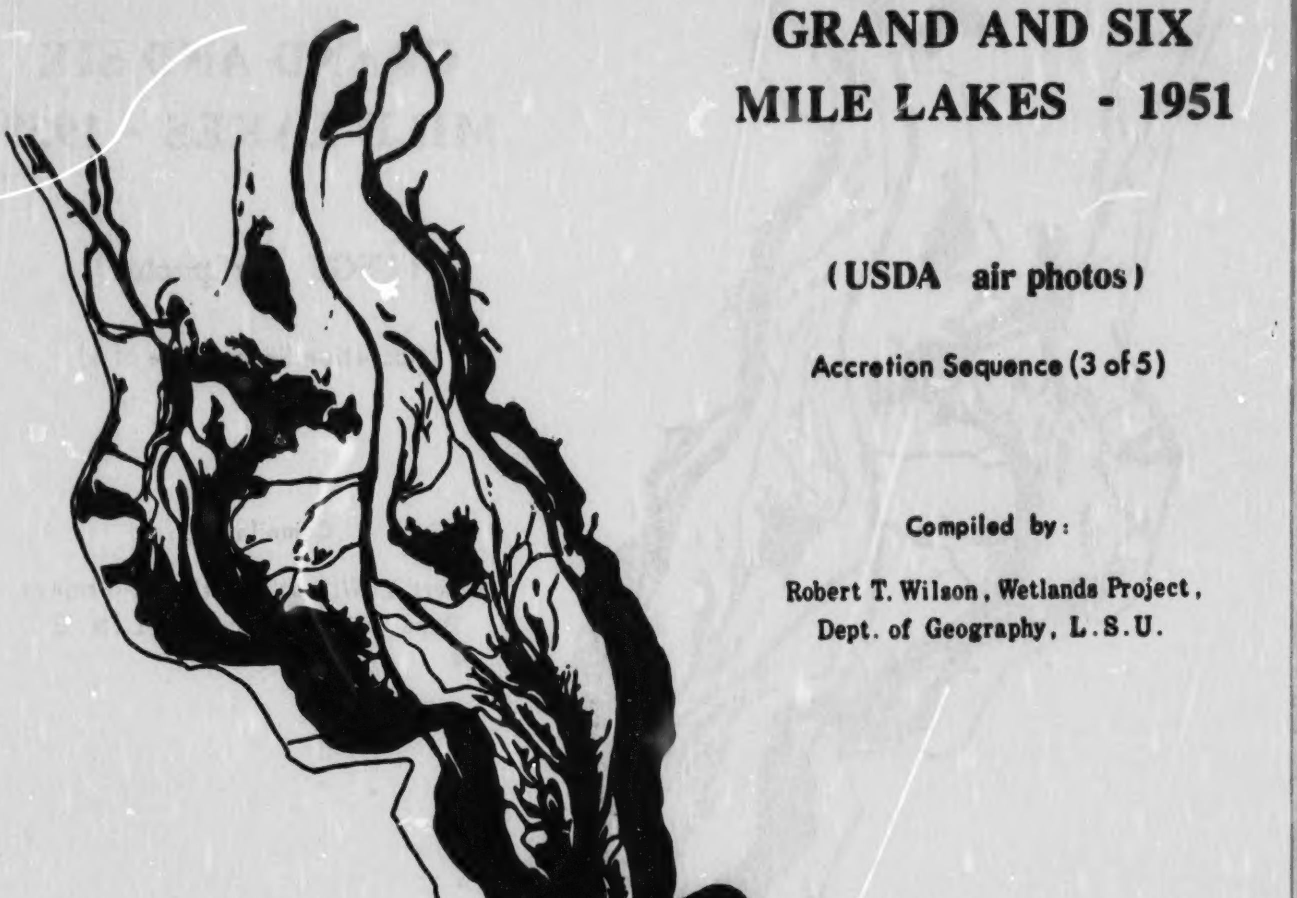
GRAND AND SIX MILE LAKES - 1951
(USDA air photos)
Accretion Sequence (3 of 5)
Compiled by:
Robert T. Wilson, Wetlands Project, Dept. of Geography, L.S.U.
N
0
5 mi.

Figure 1-7. Grand and Six Mile Lakes - 1951 (Robert T. Wilson, 1973).

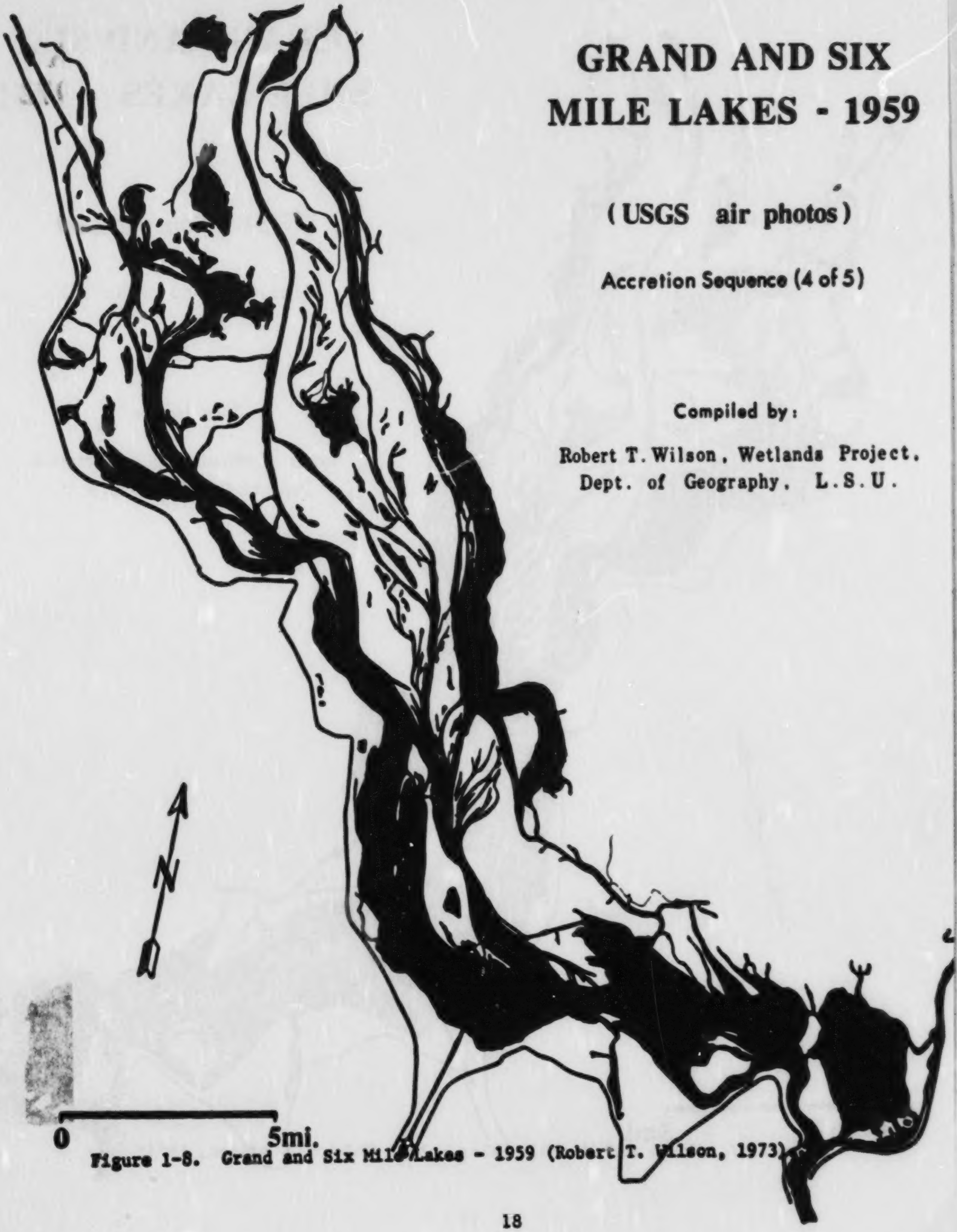
GRAND AND SIX
MILE LAKES - 1959
(USGS air photos)
Accretion Sequence (4 of 5)
Compiled by:
Robert T. Wilson, Wetlands Project,
Dept. of Geography, L.S.U.
N
0
5mi.

Figure 1-8. Grand and Six Mile Lakes - 1959 (Robert T. Wilson, 1973)

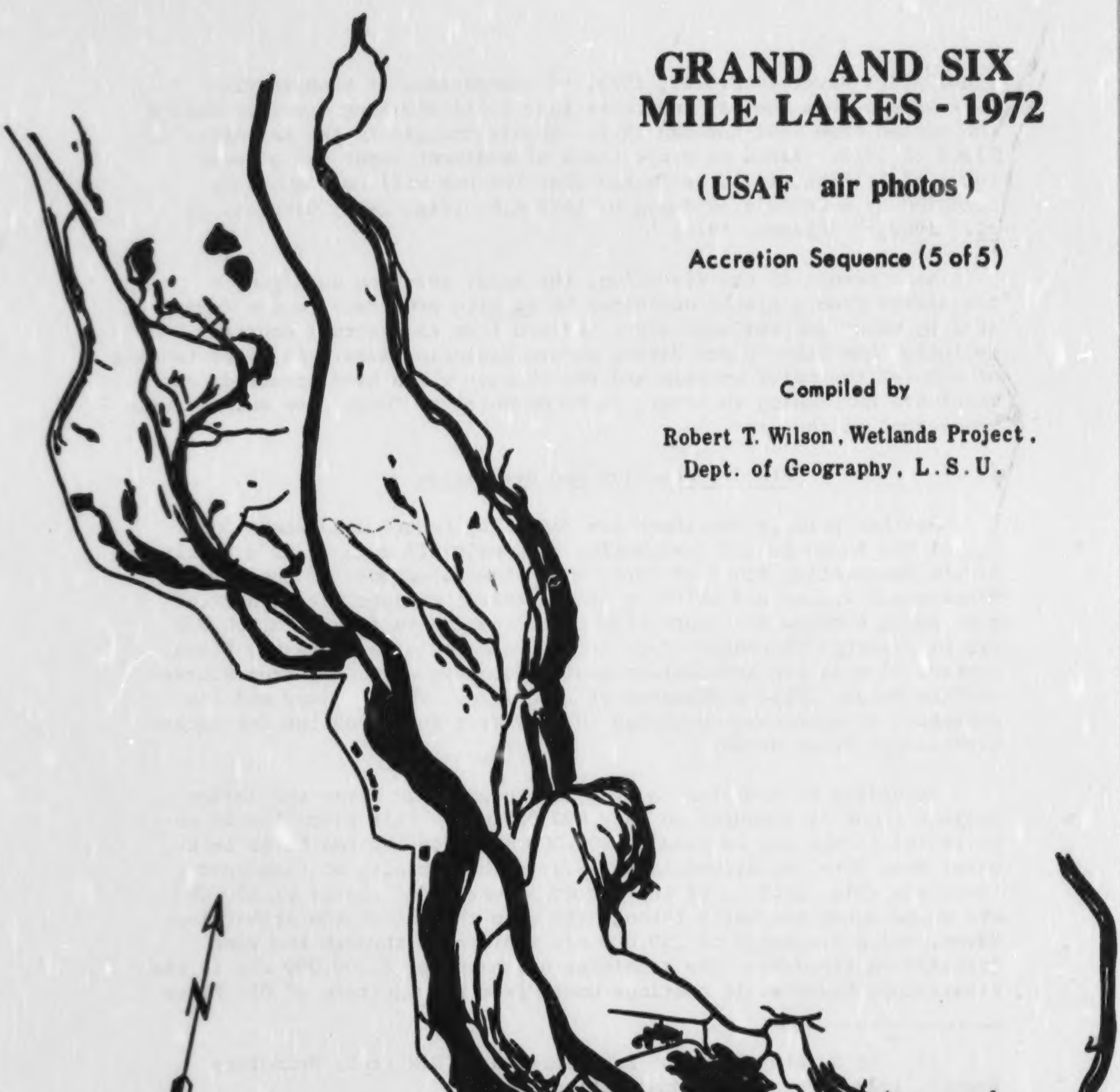
GRAND AND SIX MILE LAKES - 1972
(USAF air photos)
Accretion Sequence (5 of 5)
Compiled by
Robert T. Wilson, Wetlands Project,
Dept. of Geography, L.S.U.
N
0
5mi.

Figure 1-9. Grand and Six Mile Lakes - 1972 (Robert T. Wilson, 1973)

Atchafalaya River (U.S.C.E., 1973).[15] Comparison of bathymetric survey data from the bay indicates that rapid shoaling occurred during the period from 1952 through 1972. Shoals emerged in the bay after the flood of 1973. Based on projections of sediment input and present rates of filling, it is estimated that the bay will be completely occupied by a deltaic landmass by 1990 A.D. (Fig. 1-10; Garrett, *et al.*, 1969;[16] Shlemon, 1972).[17]

As a result of the diversion, the study area has undergone a transition from a system dominated by *in situ* processes to one dominated by water and sediment input derived from an external source. This evolution has taken place during modern historic times. An understanding of each of the major systems and the changes which have occurred, and which are continuing to occur, is fundamental to future use and resource management of the area.

Flood Protection and Navigation

Another primary consideration regarding future management and use of the basin is its designation as a major floodway. As a result of the devastating flood of 1927, which inundated most of the Lower Mississippi Valley and Delta, a flood control project was authorized that would provide for protection of the region in case of 3,000,000 cfs Mississippi discharge (Fig. 1-11). A major element in the flood control plan is the Atchafalaya Basin floodway, extending from Simmesport to Morgan City, a distance of 140 miles. The floodway and its attendant structures are designed to provide a relief outlet for excess Mississippi River water.

According to the plan, at the latitude of Old River the design project flood is computed to be 3,000,000 cfs. This floodflow is to be routed to the sea by passing 900,000 cfs from the Red River backwater area into the Atchafalaya Basin in the vicinity of Simmesport, Louisiana (Fig. 1-12). Of the latter amount, a discharge of 650,000 cfs would enter the basin through the main channel of the Atchafalaya River, and a discharge of 250,000 cfs would pass through the West Atchafalaya Floodway. The remaining discharge of 2,100,000 cfs in the Mississippi River would continue south from the latitude of Old River

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[15] U. S. Army Corps of Engineers, N.O. District, Hydrology Branch, 1973. Personal Communication.

[16] B. J. Garrett, R. Hawhurst, and R. J. Miller, *Atchafalaya Basin, Louisiana: Lower Atchafalaya River and Wax Lake Outlet*. (U. S. Army Corps of Eng., New Orleans Dist., presented at the 66th meeting of the Comm. on Tidal Hydraulics, 1969).

[17] Roy J. Shlemon, *Development of the Atchafalaya Delta, Louisiana*, (Hydrologic and Geologic Studies of Coastal La., Rept. No. 13, C.S.I., L.S.U., Baton Rouge, La., 1972).

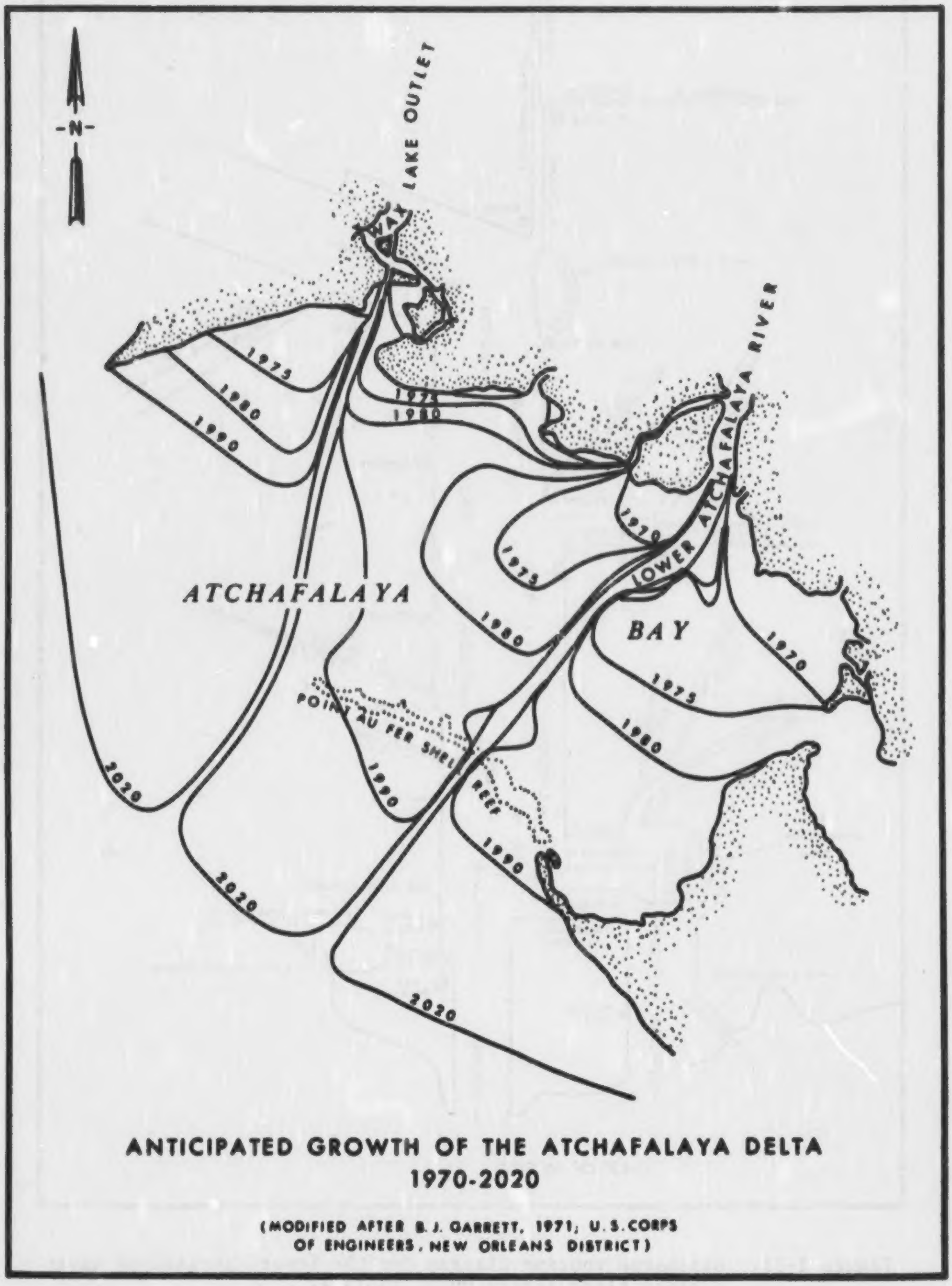
-N-
WAX
LAKE OUTLET
LOWER ATCHAFALAYA RIVER
ATCHAFALAYA
BAY
POINT AU FER SHELL REEF
1970
1975
1980
1990
2020
ANTICIPATED GROWTH OF THE ATCHAFALAYA DELTA
1970-2020
(MODIFIED AFTER B. J. GARRETT, 1971; U. S. CORPS OF ENGINEERS, NEW ORLEANS DISTRICT)

Figure 1-10. Anticipated configuration of the Atchafalaya Delta shoreline by the year 2020 (after Garrett, et al., 1969).[18]

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[18] B. J. Garrett, 1969, op. cit.

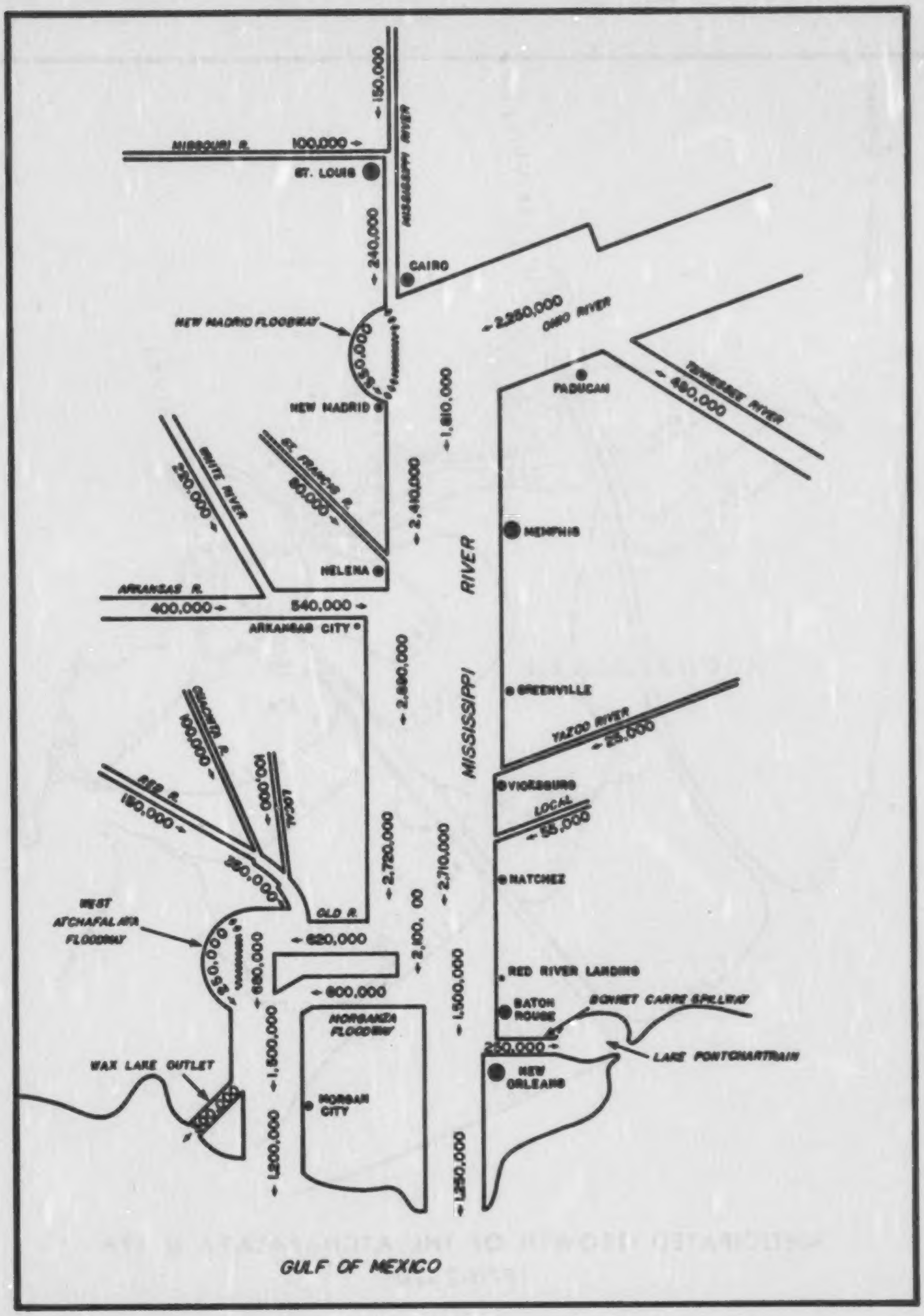
150,000
MISSISSIPPI RIVER
MISSOURI R.
100,000
ST. LOUIS
240,000
CAIRO
NEW MADRID FLOODWAY
550,000
2,250,000
OHIO RIVER
PADUCAH
TENNESSEE RIVER
480,000
NEW MADRID
1,810,000
WHITE RIVER
230,000
ST. FRANCIS R.
60,000
2,410,000
MEMPHIS
HELENA
ARKANSAS R.
400,000
540,000
RIVER
ARKANSAS CITY
2,890,000
MISSISSIPPI
GREENVILLE
YAZOO RIVER
25,000
OUACHITA R.
100,000
LOCAL
100,000
RED R.
180,000
VICKSBURG
LOCAL
55,000
250,000
2,720,000
2,710,000
NATCHEZ
WEST
ATCHAFALAYA
FLOODWAY
OLD R.
620,000
250,000
680,000
2,100, 00
1,500,000
RED RIVER LANDING
600,000
BATON ROUGE
BONNET CARRE SPILLWAY
MORGANZA FLOODWAY
250,000
LAKE PONTCHARTRAIN
WAX LAKE OUTLET
1,500,000
NEW ORLEANS
MORGAN CITY
1,200,000
1,250,000
GULF OF MEXICO

Figure 1-11. Discharge routing diagram for the Lower Mississippi River project flood (after USCE, 1967).[19]

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[19] U. S. Army Corps of Engineers, Flood Control in the Lower Mississippi River Valley (Vicksburg, Mississippi: Engineers Division, 1967).

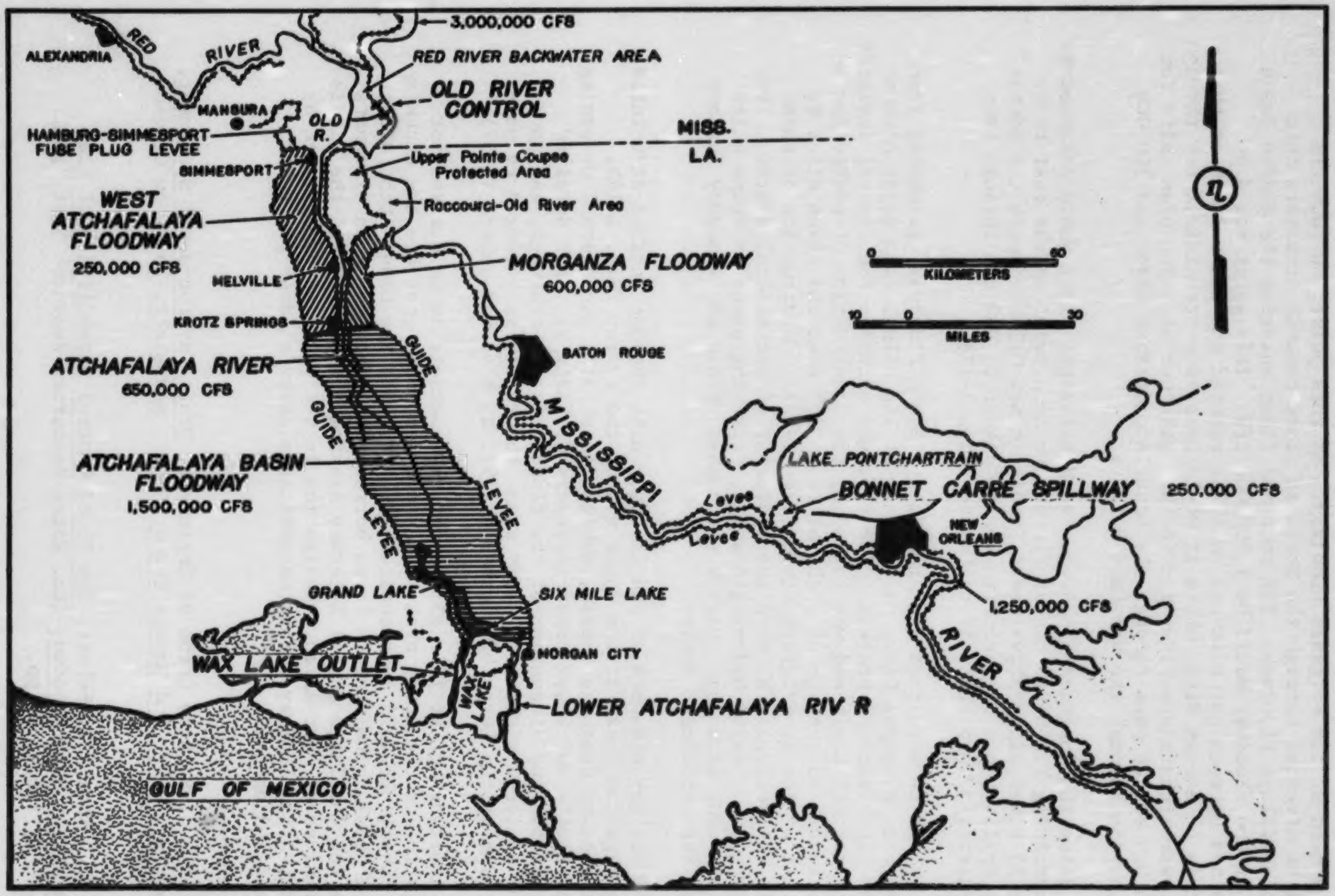
3,000,000 CFS
ALEXANDRIA
RED RIVER
RED RIVER BACKWATER AREA
OLD RIVER CONTROL
MANSURA
OLD R.
HAMBURG-SIMMESPORT FUSE PLUG LEVEE
MISS.
LA.
Upper Pointe Coupee Protected Area
SIMMESPORT
Raccourci-Old River Area
WEST ATCHAFALAYA FLOODWAY
250,000 CFS
MORGANZA FLOODWAY
600,000 CFS
MELVILLE
0 KILOMETERS 60
10 0 MILES 20
KROTZ SPRINGS
GUIDE
BATON ROUGE
ATCHAFALAYA RIVER
650,000 CFS
GUIDE
MISSISSIPPI
LAKE PONTCHARTRAIN
ATCHAFALAYA BASIN FLOODWAY
1,500,000 CFS
LEVEE
Levee
BONNET CARRE SPILLWAY
250,000 CFS
LEVEE
Levee
NEW ORLEANS
GRAND LAKE
SIX MILE LAKE
1,250,000 CFS
MORGAN CITY
WAX LAKE OUTLET
RIVER
WAX LAKE
LOWER ATCHAFALAYA RIV R
GULF OF MEXICO

Figure 1-12. Planned use of the Atchafalaya Basin for directing part of a projected 3,000,000 cfs flood (after Chatry, 1961)[20]

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20. Frederic M. Chatry, Flood Distribution Problems below Old River (Trans. Amer Soc. Civ. Eng., 126, Part I 1961), p. 118.

to the head of the Morganza Floodway. At this point, 600,000 cfs would be diverted through the Morganza flood control structure into the Atchafalaya Floodway. The combined flows entering the middle basin area of the floodway would be 1,500,000 cfs. This water would be contained between guide levees until it reached the Teche Ridge at the latitude of Morgan City, where it would pass into Atchafalaya Bay through the Lower Atchafalaya River and the Wax Lake Outlet. The plan calls for 1,200,000 cfs to pass through the Lower Atchafalaya River and 300,000 cfs to pass through the Wax Lake Outlet.

Below the Morganza Floodway, the Mississippi River would accommodate the remaining 1,500,000 cfs of floodwater to a point on the east bank about 33 river miles above Canal Street in New Orleans where the Bonnet Carre Spillway has been constructed to divert 25,000 cfs through Lake Pontchartrain into the Gulf of Mexico (Fig. 1-12).

It can be seen that the Atchafalaya Basin Floodway, extending from Simmesport to Morgan City, a distance of 140 miles, is a major element of the flood control project. The floodway occupies the central lowlands of the natural basin and was formed by the construction of protection or guide levees an average of eight miles to the east and seven miles to the west of the Atchafalaya River (Fig. 1-13). Construction of these levees has seriously altered the hydrology of the natural system. They have segmented major hydrologic units, depriving parts of these units from overbank flooding. Borrow pit canals within the floodway further modify the hydrologic regime.

Other key elements of the floodway plan include control structures and navigation locks at the upper end of the system (Fig. 1-14), supplementary drainage canals, navigation canals, and channel deepening in the middle and lower areas (Appendix C, Plate 2). For detailed descriptions and discussion of the flood control, drainage, and navigation projects within the study area, the reader is referred to publications by the Corps of Engineers (1972 A, B)[21] and Hebert (1967).[22]

A network of artificial and natural channels is maintained for navigation in the study area. The more important ones are the Atchafalaya River, the Gulf Intracoastal Waterway, and the Lower Atchafalaya Ship Channel. The eastern levee borrow pit functions as an alternate route for the Intracoastal Waterway linking Morgan City and the Mississippi River at Port Allen. Navigation in the basin is complicated by its use as a floodway. This necessitates locks at most points of ingress and egress.

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21. U. S. Army Corps of Engineers, Draft Environmental Statement, Atchafalaya River and Bayous Chene, Bouef, and Black, La. (New Orleans, La., 1972).

22. Kermit L. Hebert, The Flood Control Capabilities of the Atchafalaya Basin Floodway (La. Water Resources Research Inst. Bull. GT-1, LSU, 1967), 87 pp.

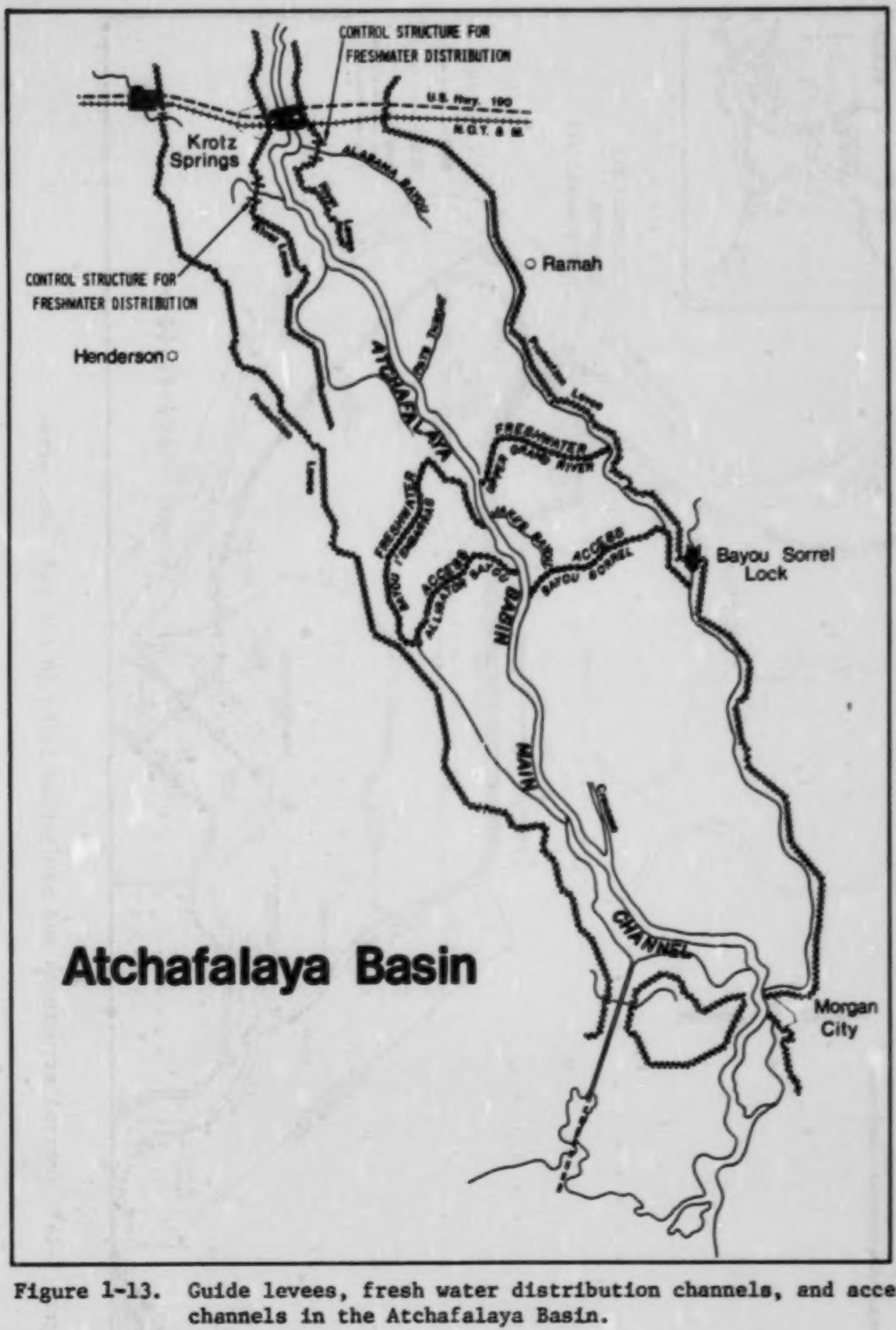
CONTROL STRUCTURE FOR FRESHWATER DISTRIBUTION
U.S. Hwy. 190
N.O.T. & M.
Krotz Springs
ALABAMA BAYOU
Ramah
CONTROL STRUCTURE FOR FRESHWATER DISTRIBUTION
Henderson
ATCHAFALAYA
Levee
FRESHWATER GRAND RIVER
JAKES BAYOU
ACCESS BAYOU SORREL
Bayou Sorrel Lock
FRESHWATER BAYOU
ACCESS ALLIGATOR BAYOU
MAIN CHANNEL
Atchafalaya Basin
Morgan City

Figure 1-13. Guide levees, fresh water distribution channels, and access channels in the Atchafalaya Basin.

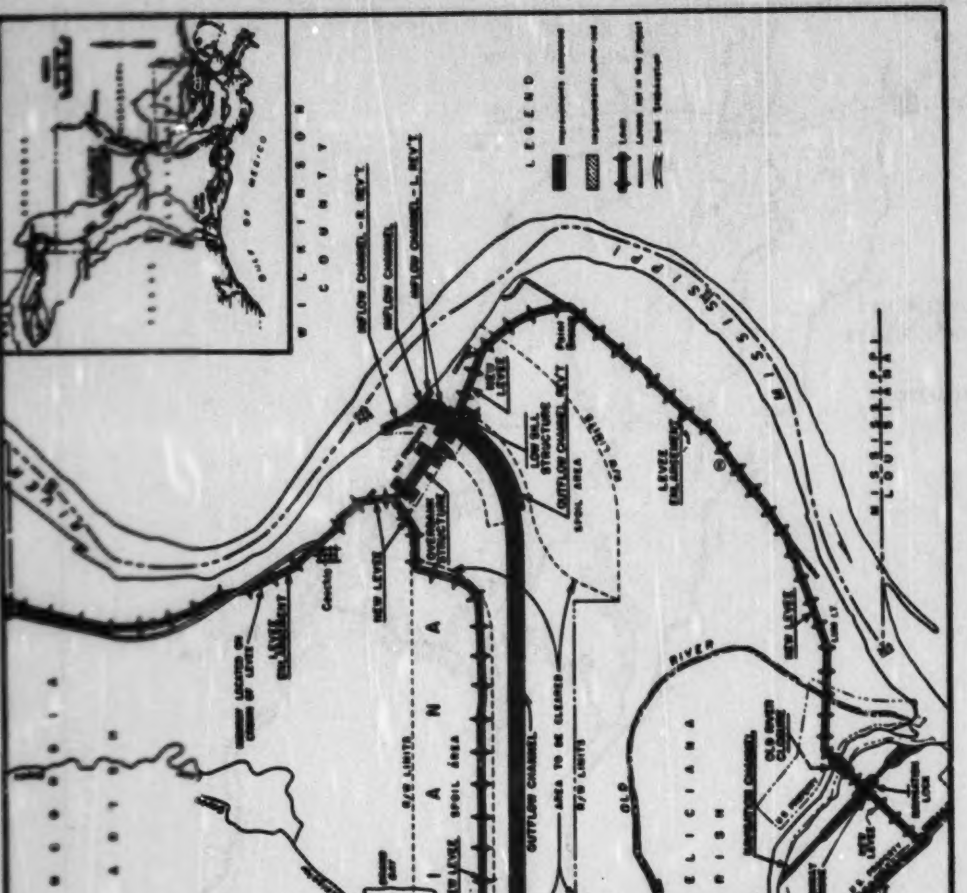
PLAN
SCALE OF MILES
N
LOUISIANA
AVOYELLES PARISH
WEST FELICIANA PARISH
POINTE COUPEE PARISH
WILKINSON COUNTY
MISSISSIPPI
LOUISIANA
MISSISSIPPI
RED
OLD
RIVER
UPPER OLD RIVER
ATCHAFALAYA
SIMMESPORT
OUTFLOW CHANNEL
AREA TO BE CLEARED
SPOIL AREA
NEW LEVEE
OVERBANK STRUCTURE
LOW SILL STRUCTURE
OUTFLOW CHANNEL
INFLOW CHANNEL
LEVEE ENLARGEMENT
NAVIGATION CHANNEL
OLD RIVER CLOSURE
LOCK
LEGEND
TEXAS
GULF OF MEXICO

Figure 1-14. Control structures and navigation locks in the Old River area.

Flood protection and drainage of local communities, agricultural, and industrial areas within and around the basin present another major consideration. The towns of Morgan City, Patterson-Berwick, Krotz Springs, and Melville are ringed by flood protection levees. Back levees and intricate drainage and pumping systems protect communities, farmland, and industry along the bordering natural levees from flooding.

Navigation and floodway uses of the natural basin have been plagued by a number of very difficult engineering problems. Siltation in the middle basin has progressively reduced the capacity of the floodway. Attempts to raise the protection levees to compensate for the filling have been frustrated by foundation failure resulting in continuous settlement of the levee crown in a number of areas.

Another recurring problem has been scour at the Old River Control Structure. A large hole with depths of more than 150 ft below normal water stages developed downstream of the structure's sill in the 1960's. Subsequently, the hole has been at least partially filled with a nonerodable layer of riprap (Hebert, 1967).[23] During the flood of 1973, the structure was again partially undermined by scour, and at this time, the damages have not yet been completely repaired. Scour undermined one of the piers of a new highway bridge located at Krotz Springs during its construction. The pier toppled and a replacement had to be rebuilt.

Since the 1950's, siltation in the Morgan City port area has been increasing and has become a persistent problem. Now that the locus of sedimentation for the entire system has shifted to Atchafalaya Bay, maintenance of navigation channels in the lower basin will be more difficult and costly.

Basin Use

For a long time the basin's resources related primarily to its natural environment of swamps, streams, and lakes interspersed with natural levee ridges. Fishing and trapping date back to prehistoric times, and timber was removed as early as the first half of the 18th century. Under influence of increased pressure for arable land and rising profits for sugarcane, land was brought into cultivation along the natural levee ridges of Bayou Maringouin, Bayou Grosse Tete, and several other small streams in the early 1900's. In their past form, these uses of the basin were mostly compatible with each other and with the natural environment.

Conflicts in the use of the basin and deterioration of its renewable resources began to arise in the late 19th century. With development of the overhead skiddy and the pull boat, lumbering became an economically profitable undertaking. A multimillion dollar industry mushroomed from the 1870's to the 1920's, with red cypress the principal target. The largest cypress mill turned out as much as 75,000 board feet per day. This activity led to total depletion of red cypress in the basin by the year 1927. Furthermore, the retrieval of trees from the swamps had necessitated the dredging of numerous canals. The canals and fringing spoil deposits were the first step in a continuing history of infringement upon the hydrologic regime of the basin, in particular, on water movement into and through the swamps.

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[23] Ibid.

Further complications developed and existing trends were altered with increased diversion of water through the Atchafalaya River and with use of the basin as a floodway. On the one hand, the increased frequency of flooding forced the abandonment of agricultural areas in the middle basin. On the other hand, progressive sedimentation from overbank flooding increased the area of bottomland in the upper basin at the expense of the wetlands. With the aid of drainage canals, and especially following partial confinement of the Atchafalaya River between artificial levees, approximately 25 percent of the upper basin could be put into use for cultivation. Though presently restricted mainly to the area north of U.S. Highway 190, agricultural interests have focused increasingly on the middle, and to some extent, on the lower basin as sedimentation progresses.

Through local runoff it is assumed that increased agricultural development has resulted in an increased influx of nutrients, as well as pollutants, related to fertilizer and pesticide applications, respectively. Consequently, the effect of agricultural development should extend to the undeveloped wetland habitats within the basin, and its effects are expected to be most salient in the Verret-Palourde and the Fausse Point sub-basins, which have been severed from annual overflow as a result of floodway levee construction. Both of these sub-basins are flanked by wide natural levee ridges where agricultural land use is dominant.

Activities related to the extraction of oil and gas have formed the third threat to the renewable resource base since the 1930's. Drilling operations, access to these operations, and transport of oil and gas by pipelines have necessitated the dredging of numerous canals These activities have resulted in the introduction of large volumes of sediment into swamps and lakes and have greatly modified the interior drainage through redirecting or blocking water movement.

Fishing remains an important element in the basin's economy, but if the period of 1963 to 1967 is any indication of the future, a declining trend is prevalent (Lindall et al., 1972).[24]

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[24] William N. Lindall, Jr., John R. Hall, James E. Sykes, and Edgar L. Arnold, Jr., Louisiana Coastal Zone: Analyses of Resources and Resource Development Needs in Connection with Estuarine Ecology (National Marine Fisheries Service, Biological Lab, St. Petersburg, Fla., 1972).

The basin is still the prime crawfish-producing area in Louisiana, accounting for a multi-million dollar annual catch. However, the area of productive habitat is being reduced progressively as a result of environmental change. Crawfish production has become increasingly concentrated in the least changed parts of the floodway, the Flat Lake and the Upper Belle River area. Among the finfishes, catfish and buffalo fish have remained the prime target of commercial fishermen, but catfish catches dropped nearly 50% from 1963 to 1967 (Lindall et al., 1972).[25] A summary of commercial fish catch is given below based on a survey by the Louisiana Wild Life and Fisheries Commission and the U.S. Army Corps of Engineers (1973)[26] for the period July, 1971 to June, 1972.

Commercial Fish Catch	$4,641,000	22,545,000 lbs
Crawfish	$3,286,000	14,287,000 lbs
Catfish	$ 780,000	2,690,000 lbs
Buffalo fish	$ 247,000	1,765,000 lbs
Other	$ 328,000	3,803,000 lbs

In recent years, recreation has become one of the most significant benefits derived from the basin's resources. The Louisiana Wild Life and Fisheries Commission considers recreation activities as primary uses of the Atchafalaya Basin, both in terms of man hours of use and capital generation. A breakdown of the recreational man hours is presented below (La. W.L.F.C. and U.S.C.E., 1973).[27]

Recreational Man Hours	10,873,000 hrs.
Sport Fishing	2,743,000 hrs.
Camping	6,871,000 hrs.
Hunting	878,000 hrs.
Other	381,000 hrs.

The majority of these recreational activities are water-oriented. Sports fishermen utilize the area on a year-round basis, particularly attracted to the largemouth bass. An indication of intensive use for sport fishing is found in the results of a 1963 nine-day survey by the Louisiana Wild Life and Fisheries Commission. The survey showed a total of 17,723 man days of sport fishing in nine days, or an average of nearly 2000 fishermen per day, with an average of 11.3 fish taken per fisherman per day.

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[25] *Ibid.*

[26] Louisiana Wild Life and Fisheries Commission and U. S. Army Corps of Engineers, N. O. District, 1973, *Atchafalaya Basin Usage Study* (Interim Report, July 1, 1971-June 30, 1972).

[27] *Ibid.*

Among the recreational fishing activities, crawfishing is the most unique element. In many cases it has become a pastime for whole families and other groups, as well as for individuals. Recreational crawfishing is engaged in during the spring months with a peak during May and June. Official harvest data are not available, but estimates have been made of some one million pounds of crawfish per year (L.W.L.F.C. and U.S.C.E., 1973).[28]

Hunting activities are important within the basin. Duck hunting is popular, as well as hunting for deer and smaller animals. The basin provides possibly the best woodcock hunting in the nation.

Boating occurs in the basin incidentally to other pursuits, such as fishing and hunting. However, there is also a substantial number of purely recreational boaters within the basin. The Atchafalaya can be considered a truly outstanding boating area due to the hundreds of miles of navigable waterways and numerous expanses of open waters. Besides the numerous small boats, the Atchafalaya will accommodate larger pleasure craft through its main channel and the Port Allen-Morgan City waterway. Easy access to this area from other pleasure craft areas in the Gulf Coastal area increases the potential of boating.

Much of the camping in the basin is associated with hunting and fishing activities, but there is an increasing amount of family and scout camping. Most of the camping is done in permanent camps, either houseboats or small buildings, rather than tents, etc. The number of such camps may range from five hundred to a thousand or more units, but continue to grow in number each year. The majority of these are only occupied on weekends and holidays.

Water skiing, picnicing, auto sightseeing, and nature studies are other recreational activities that are engaged in within the basin. Man hours spent in these types of activities may be as much as 170,000 hrs. annually (L.W.L.F.C. and U.S.C.E., 1973).[29] The basin's capacity for accommodating some of the above uses seems almost unlimited.

Problem Defined

The main problem in the Atchafalaya Basin is one of land and resource uses, that in their present form, are mutually incompatible and environmentally detrimental. In the first instance, both aspects relate to water surface management. Sustaining the basin as a highly productive biological resource and an area of unlimited recreational possibilities requires an adequate water supply, a channel-basin system that allows for overbank flooding without an excess influx of sediment, and a circulation that will prevent oxygen deficiencies. Indiscriminate routing of oil and gas pipelines, dredging of pipeline canals, and streams, and deposition of spoil have long counteracted realization of the above conditions, and in various cases still do. To a certain extent, detrimental impact of practices employed in dredging and spoil disposal associated with pipeline canals is presently diminished as a result of their regulation by the Louisiana Wild Life and Fisheries Commission.

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[28] Ibid.

[29] Ibid.

Agricultural development requires reduction of annual flooding and reduced water levels. Under present conditions, this results in excessive de-watering or insufficient flooding of the overflow swamps. In addition, a conflict arises when Mississippi discharges require use of the central basin as a floodway.

Present condition and use of the basin as a floodway are in conflict with urban development at its lower end, with agricultural development at its upper end, and with the natural environment. In regard to the latter, the conflict stems primarily from a reduction of overflow as a result of efforts to improve hydraulic efficiency through dredging. This conflict has become even more urgent with the recent proposal by the U.S. Army Corps of Engineers for construction of the so-called Center Channel. The objective here is to enlarge the present cross-sectional area of the main channel from 60,000 to 100,000 ft^2 in order to enlarge the ratio of channel flow to overbank flow during passage of flood waters through the basin.

The Center Channel plan has met considerable opposition, stemming largely from the fear that implementation would greatly modify the natural flooding and de-watering cycle. Additional concern relates to the possibility that proposed channel dimensions are not in equilibrium with mean annual flow and would lead to extensive channel siltation. This, in turn, would necessitate massive dredging and spoil disposal problems.

Water and land based transportation have resulted in other problems. Navigation channels presently divert large amounts of sediment from the main channel into areas of the basin where reduction of flow velocity causes deposition. Associated with the accumulation of sediment are problems of backwater siltation and reduced circulation in overflow swamps.

The recently completed section of Interstate-10 between Lafayette and Baton Rouge crosses the basin. Though elevated on structures throughout the length of the basin, the highway provides two access points or off ramps within the basin proper, creating the possibility of high density recreational development. These areas will become increasingly important as the state of Louisiana considers development of a tourist-oriented interpretive center in or at the margin of the basin in close proximity to I-10.

Man's attempts to control the Atchafalaya diversion, to use the basin as a floodway, and for other purposes have placed stresses on the natural environment and have precluded making optimum use of the basin's resources. Detrimental changes have occurred and are predicted to increase in the future if no management measures are taken. In an effort to resolve conflicts and determine optimum land and resources use in the basin, a series of studies has recently been initiated by various state and federal agencies. All of these will hopefully contribute to development and implementation of a multiuse and environmental management plan. Toward that goal, the present study concerns itself primarily with the surface water resources of the basin and their potential for management.

The natural environment of the basin dictates that land use is ultimately determined by the hydrologic regime, with water quality an integral part. Optimum use of the area will therefore require an effective water management plan based on an understanding of water needs required to sustain or improve present ecosystems in parts or all of the basin, and on consideration of the effects arising from possible types of land use. In concept, such a plan must recognize environmental opportunities and constraints, while at the same time allowing man to make adaptations of the environment necessary for his successful use and occupation of the land.

SECTION IV

APPROACH

The Atchafalaya Subsystem

As a basic point of departure for development of a water resource management plan, the Atchafalaya Subsystem should be viewed as the product of interaction between physical, chemical, biological, and human systems (Fig. 4-1). It is the understanding of the natural and human processes operating and the manner in which these processes interact on which effective planning depends. Only when the most important stores and regulators of the system can be identified and understood will it be possible to intervene intelligently in the system's operation. This means, in effect, the translation of knowledge concerning the physical, biological, and human processes operating in the Atchafalaya into a true control system (Chorley and Kennedy, 1971).[30]

Much progress towards this goal has been made in recent years. Riverine and deltaic research increasingly allow the expression of relationships between process and form data. Conceptual and quantitative models which depict and explore process-response relationships have evolved. Applicable models of sedimentation include, for example, the quantitative models of Harbaugh and Bonham Carter (1970)[31] and the recent work of Wright and Coleman (1973).[32]

Similarly, major contributions have been made through the application of the systems theory in dealing with biological systems. With respect to the coastal environment, the work of E. P. Odum (1961)[33] dealing with estuarine food chains may be cited. Many examples of the systems approach can be found with regard to cultural, economic, and social processes (Chorley and Haggett, 1967).[34]

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[30] R. J. Chorley and B. A. Kennedy, Physical Geography, A Systems Approach (Prentice Hall International Inc., London, 1971), p. 39.

[31] John W. Harbaugh, and Bonham-Carter, Graeme, Computer Simulation in Geology (Wiley-Interscience, N.Y., 1970), 575 pp.

[32] L. D. Wright and James Coleman, Variations in Morphology of Major River Deltas as Functions of Ocean Wave and River Discharge Regimes (Jour. Amer. Assoc. of Petro. Geologists, 1973).

[33] E. P. Odum, The Role of Tidal Marshes in Estuarine Production (The Conservationist, vol. 15, No. 6, 1961), pp. 12-15.

[34] R. J. Chorley and P. Haggett Eds., Models in Geography (Methuen, London, 1967), p. 41.

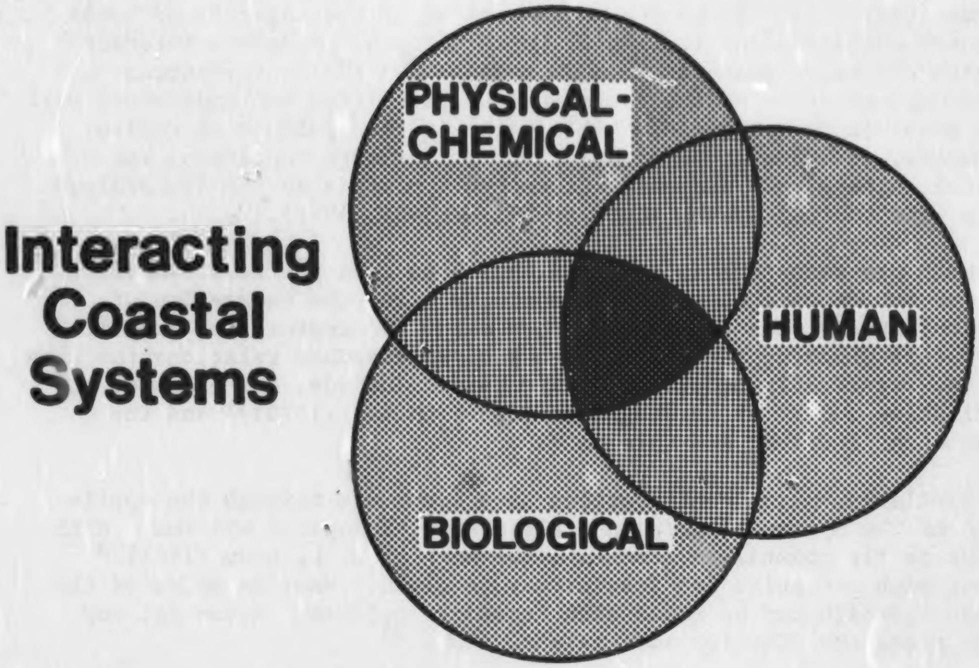
Interacting
Coastal
Systems
PHYSICAL-
CHEMICAL
HUMAN
BIOLOGICAL

Figure 4-1. Interacting cultural and natural systems related to coastal zone management.

The Mississippi Delta system has long served as a natural laboratory for the study of deltaic processes. These studies have led to a general and sometimes detailed understanding of the manner in which the overall system functions (see for example Fisk, 1955,[35] 1960:[36] Gagliano and van Beek, 1970;[37] Kolb and van Lopik, 1966;[38] Morgan, 1967;[39] Russell, et al., 1936).[40] With regard to environmental management, the most important knowledge that has resulted from these studies concerns the capacity of the system to maintain itself through renewal, and the process-form-material relationships that characterize the various deltaic environments and control their temporal and spatial distribution.

The self-maintaining nature of the delta system is evident in its well-documented geologic history and in the present surface configuration. These show us a sequence of delta building and abandonment in some state of balance. New delta complexes develop at the expense of older delta complexes with progradation and aggradation in one area being coexistent with deterioration in other areas. As time progresses, each complex goes through a cycle leading from initial progradation with individual cycles overlapping in time and space. The product of these cyclic and sequential changes is a highly diversified assemblage of environments... all in a changing and constantly evolving relationship.

A major diversion of the Mississippi River into the Atchafalaya Basin has been unfolding during historic times and continues to develop. This diversion represents a new cycle of delta growth. Consequently, past diversions and episodes of delta development may be used as models to improve our understanding of the processes associated with such events and to predict future conditions.

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35. H. N. Fisk, 1955, op. cit.

36. H. N. Fisk, 1960, op. cit.

37. S. M. Gagliano and T. L. van Beek, Geologic and Geomorphic Aspects of Deltaic Processes, Mississippi Delta System (Hydrologic and Geologic Studies of Coastal Louisiana, Vol. 1, Center for Wetland Resources, L.S.U., Baton Rouge, La., 1970), 140 p.

38. J. R. Van Lopik, Recent Geologic and Geomorphic History of Central Coastal Louisiana (Tech. Rept. No. 7, C.S.I., L.S.U., 1955).

39. J. P. Morgan, Ephemeral Estuaries of the Deltaic Environments (Tech. Report No. 46, CSI, LSU, Baton Rouge, La., 1967).

40. R. J. Russell and H. V. Howe, et al., Lower Mississippi Delta, Reports on the Geology of Plaquemines and St. Bernard Parishes (Louisiana Geological Survey, Geol. Bull., No. 8, 1936), pp. 1-454.

Hierarchical Classifications

A hierarchical classification of natural and cultural elements has been used throughout the study. As illustrated in Table 4-1, the broadest categories identify the study area as the Atchafalaya Distributary Subsystem of the Mississippi Delta System. Within the subsystem, four major complexes can be defined. Three of these, channel, levee, and marine delta, are intimately linked by the throughflow of Atchafalaya water and sediment. Individual complexes are defined by a suite of individual environmental units and subunits. These represent the basin building blocks of the landscape and fundamental units of the study. Management units are clusters of environmental units and represent somewhat arbitrary subdivisions of the complexes. They are defined on the basis of present land use and environmental conditions and, as the name implies, are delineated as an aid for developing a management plan.

Major Process Factors

The Atchafalaya Subsystem is an elongated zone of interactions between fluvial and marine processes, complicated by a central interior basin. Some of the major factors that influence the character of the subsystem are indicated in Fig. 4-2. Various possible combinations of these factors, coupled with the element of time, result in a dynamically changing complex of environments within the region.

In order to understand the development of characteristic forms associated with various parts of the Atchafalaya, it is necessary to review the gross factors operating on the subsystem. In addition to receiving a portion of the Mississippi flow, the Atchafalaya River accommodates the total flow of the Red River. The average annual discharge of the Atchafalaya River at Simmesport is shown in Fig. 4-3. Maximum flow recorded at Simmesport was 690,000 cfs on April 30, 1945, and the average annual flow for the period 1945-1968 at Morgan City was 148,000 cfs. During the severe flood of 1973, maximum discharges through the floodway were around 1 million cfs, which must be considered the maximum capacity of the floodway under present conditions.

As shown in Fig. 4-4, high flows occur from January to July. The average monthly flow reaches a maximum of 325,000 cfs in April, decreasing to a minimum of 73,000 cfs in September. There is a pronounced low water stage from August through November.

Average annual suspended sediment transported by the river has been determined to be 72 million cubic yards per year for the period 1965-1970 (U.S.C.E., 1973).[41] The suspended load consists of about 25 percent sand and 75 percent silt and clay. Approximately 76 percent

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[41] U. S. Army Corps of Engineers, 1973, op. cit.

Table 4-1. Classification Hierarchy of Natural and Cultural Elements of the Atchafalaya Subsystem

SYSTEM	**MISSISSIPPI DELTA**			
SUBSYSTEM	**ATCHAFALAYA**			
COMPLEX	**CHANNEL**	**LEVEE**	**FLOODBASIN**	**MARINE DELTA**
(MANAGEMENT UNIT)*				
ENVIRONMENTAL UNITS	Trunk Distributary Lacustrine Delta (active) (Canal)	Ridge Point Bar & Accretion Ridge Crevasse (Artificial Levee) (Spoil)	Cross Basin Stream Drainage Stream Channel Lake Abandoned Lacustrine Delta Trapped Depression Natural Levee Rounded Lake Pond Swamp Bottomland Marsh (Agriculture) (Canal) (Canal Network) (Borrow Pits)	Channels Subaqueous deltas Bars Delta Front Prodelta Bay Bottom Reef Mudflats
SUBENVIRONMENTS (not specified)				

*Management units are clusters of environmental and land use units delineated for planning purposes.

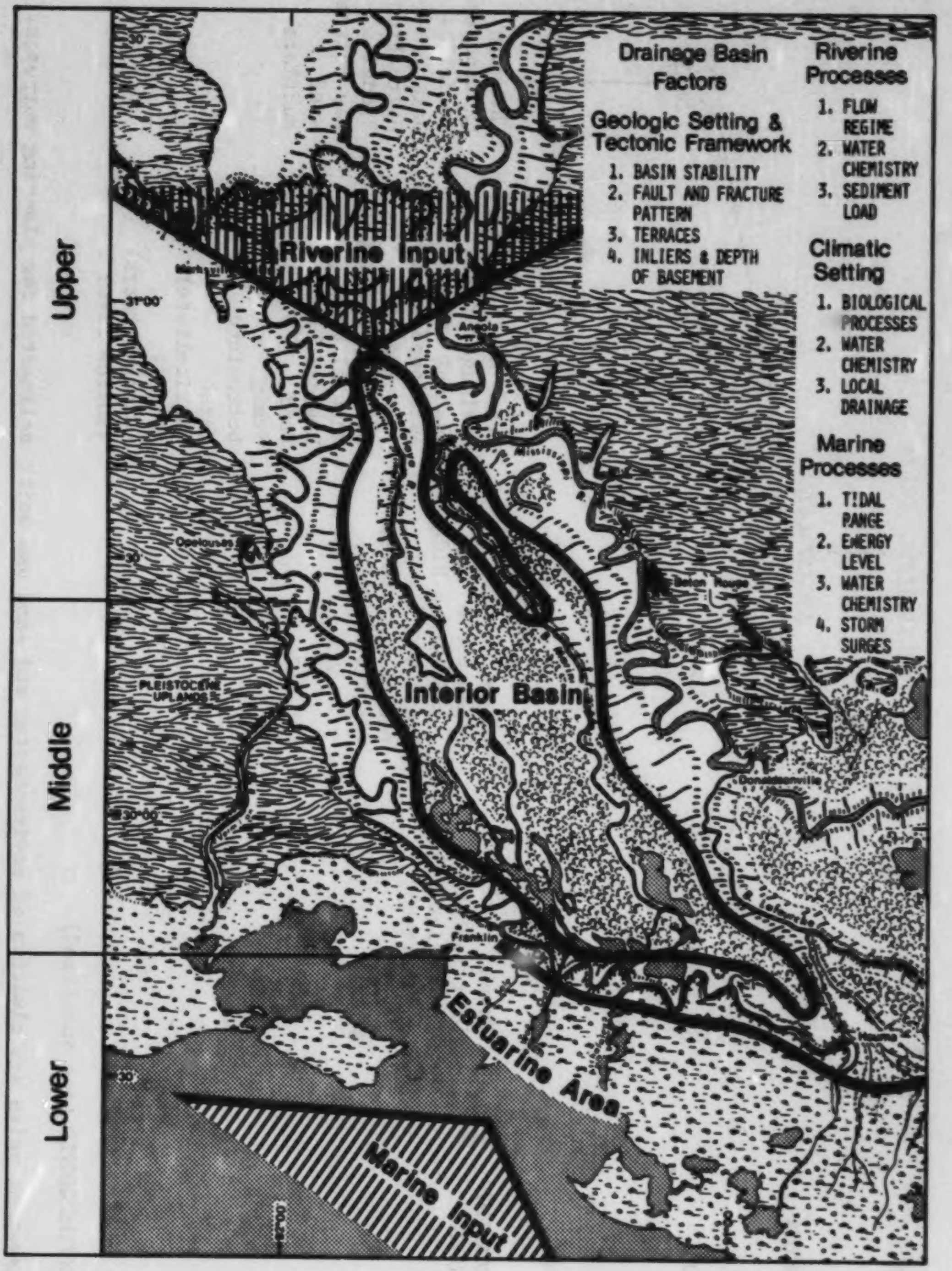
Upper
Middle
Lower
Drainage Basin Factors
Geologic Setting & Tectonic Framework
1. BASIN STABILITY
2. FAULT AND FRACTURE PATTERN
3. TERRACES
4. INLIERS & DEPTH OF BASEMENT
Riverine Processes
1. FLOW REGIME
2. WATER CHEMISTRY
3. SEDIMENT LOAD
Climatic Setting
1. BIOLOGICAL PROCESSES
2. WATER CHEMISTRY
3. LOCAL DRAINAGE
Marine Processes
1. TIDAL RANGE
2. ENERGY LEVEL
3. WATER CHEMISTRY
4. STORM SURGES
Riverine Input
Interior Basin
Estuarine Area
Marine Input
31°00'
Angola
Opelousas
30
Baton Rouge
PLEISTOCENE UPLANDS
30°00'
Franklin
Houma
30
92°00'

Figure 4-2. Major factors influencing the Atchafalaya subsystem.

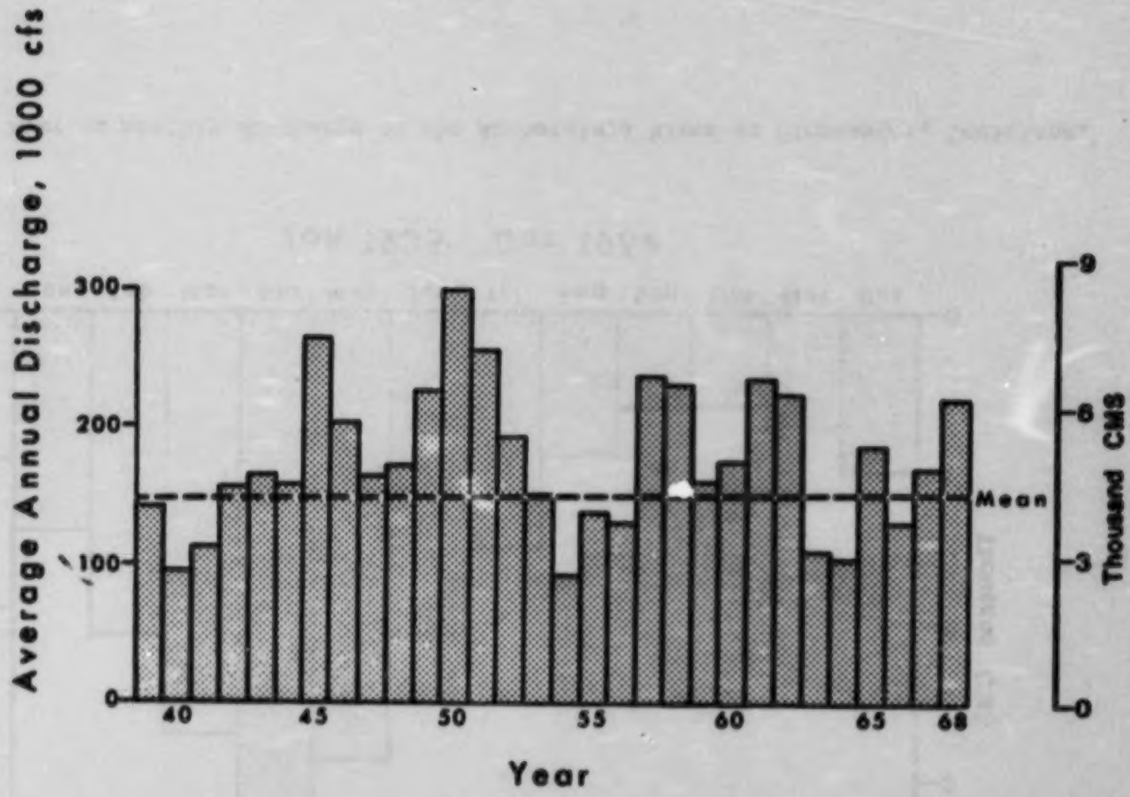

Figure 4-3. Monthly annual discharge of the Atchafalaya River at Simmesport, Louisiana.

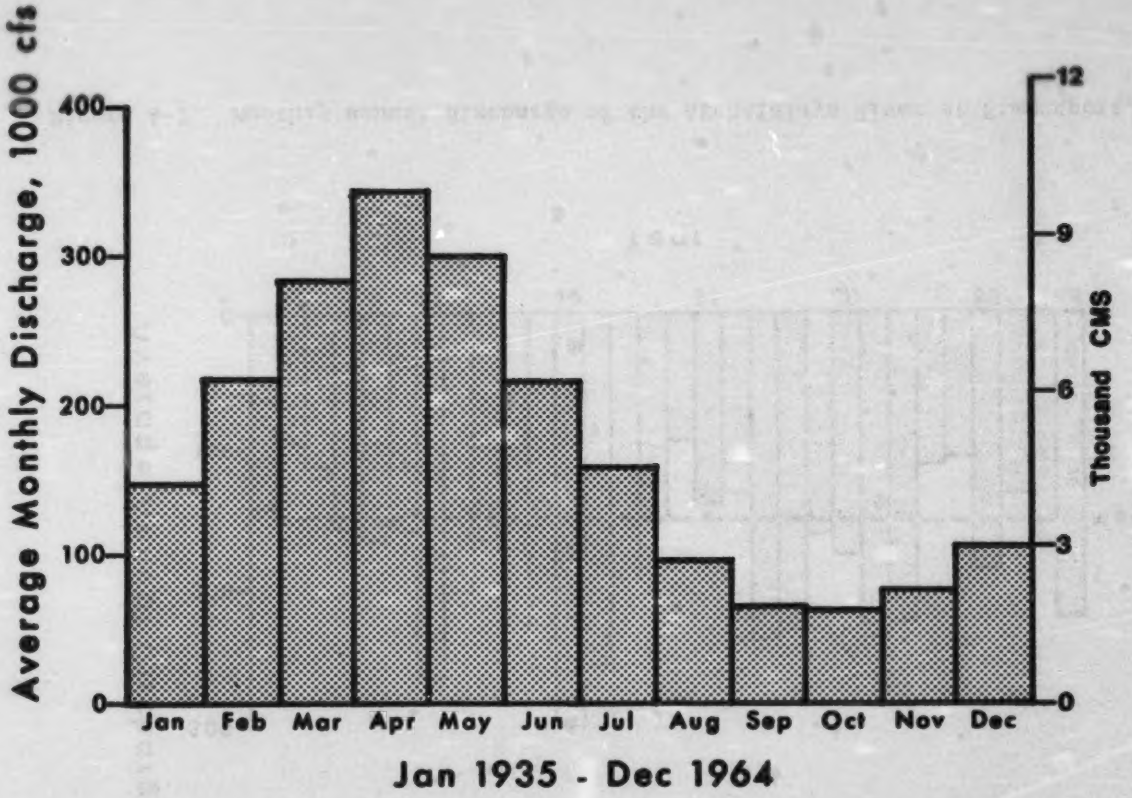

Figure 4-4. Average monthly discharge of the Atchafalaya River at Simmesport, Louisiana.

of this material was carried during high-flow period extending from January to June.

The climate of the basin is humid and warm throughout much of the year. The average annual temperature is approximately 68° F with monthly averages ranging from a low of 53° F to a high of 82° F in July. Extreme temperatures of 2° F and 110° F have been recorded in the vicinity of the basin. Average annual precipitation is 58 in., while annual extremes range from 38 in. to 113 in. While rainfall is heaviest during spring and fall months, it can be expected throughout the year.

The lower end of the basin is subject to pronounced marine effects, including weakly developed sea breeze and tropical hurricanes, as well as lesser cyclones. Several strong southeasterners may be anticipated each year, and hurricanes have a frequency of roughly one every two years in the Atchafalaya Bay area. Hurricanes may be accompanied by winds in excess of 100 mph, torrential rainfalls, and high tides. Storm generated tides at Morgan City have reached 8.5 ft.

Astronomical tides (periodic tides) of the Atchafalaya Bay area are mixed semi-diurnal and diurnal, having a mean range of approximately 1.5 ft and an extreme range of 2.7 ft. The meterological tides (wind tides), which are independent of the astronomical tides, seaward of the Point au Fer Shell Reef average +1.6 ft. with strong southeasterly winds and -2.5 ft. with strong northerly winds. Rapid water level fluctuations of the same order of magnitude occur within the bays proper. Tidal fluctuations may extend inland about 60 miles during low river stage.

The movement of water in the Atchafalaya Subsystem in response to river floods and tides represents a huge volume of energy input which drives and to a large extent, dominates the system. This energy is largely concentrated in channels and passes where high discharges, velocities, and turbulences occur. Measurements of the magnitudes, durations, and distributions of some indices of water energy will be presented in later sections of this report.

The geologic and tectonic setting influence the overall character of the subsystem. The study area lies within the Gulf Coast geosyncline a subsiding portion of the earth's crust in which great thicknesses of sedimentary deposits have accumulated over millions of years. Most of the sediments in the more than 5-mile deep geosynclinal depression were deposited in shallow marine, coastal, and deltaic environments, so that present conditions in the Gulf Coast region to a large extent represent a continuation of a very long sequence of similar events.

As a by-product of exploration for rich subsurface mineral deposits, the geological history of the area is well known. The reader is referred to Fisk (1962),[42] Van Lopik (1955),[43] Coleman (1966),[44] Frazier (1967),[45] and Shlemon (1972).[46] It is pertinent that the area is dominated by poorly consolidated sedimentary rocks, and surface features are entirely a product of Late Quaternary coastal and deltaic events. Diaperic salt domes and east-west trending down-to-the-coast growth faults are the major structural elements and dictate distribution of mineral deposits. Six intrusive salt dome structures with surface expression occur near, or within, the immediate vicinity of the study area.

Reduction in levels due to compaction and/or subsidence are very important geological processes occurring within the basin. Compaction is a type of foundation failure which occurs when load is placed on incompetent sedimentary deposits such as peats and highly plastic clays. Load may be in the form of denser sedimentary deposits such as the clay-silts of a natural levee ridge or artificial levees, highway embankments, or other man-made structures. Compaction of underlying material may cause sinking of the surface feature. A related phenomena is lateral flowage, or squeezing of the softer sediment. The probability of compaction and lateral flowage is high throughout the interior basin because of thick accumulations of clays and peats deposited in lacustrine and swamp environments, which dominated a large part of the area during late Quaternary times. These deposits may be in excess of 100 ft.

A good example of the significance of settlement through compaction is found in the progressive sinking of levees along the floodway in the middle basin. The cumulative settlement of levee crowns of the East Atchafalaya Basin Protection Levees from the time of construction until January 1963 is shown in Fig. 4-5. The average settlement of the crown on the east basin levee above Bayou Sorrel Lock was about 15 ft., with

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[42] H. N. Fisk, 1952, op. cit.

[43] J. R. Van Lopik, Recent Geologic and Geomorphic History of Central Coastal Louisiana (Tech. Rept. No. 7, C.S.I., L.S.U., 1955).

[44] James M. Coleman, Ecological Changes in a Massive Freshwater Clay Sequence (Gulf Coast Assn. of Geol. Soc., 16, 1966, also C.S.I. Tech. Rpt. No. 31) pp. 159-174.

[45] D. E. Frazier, 1967, op. cit.

[46] Roy J. Shlemon, 1972, op. cit.

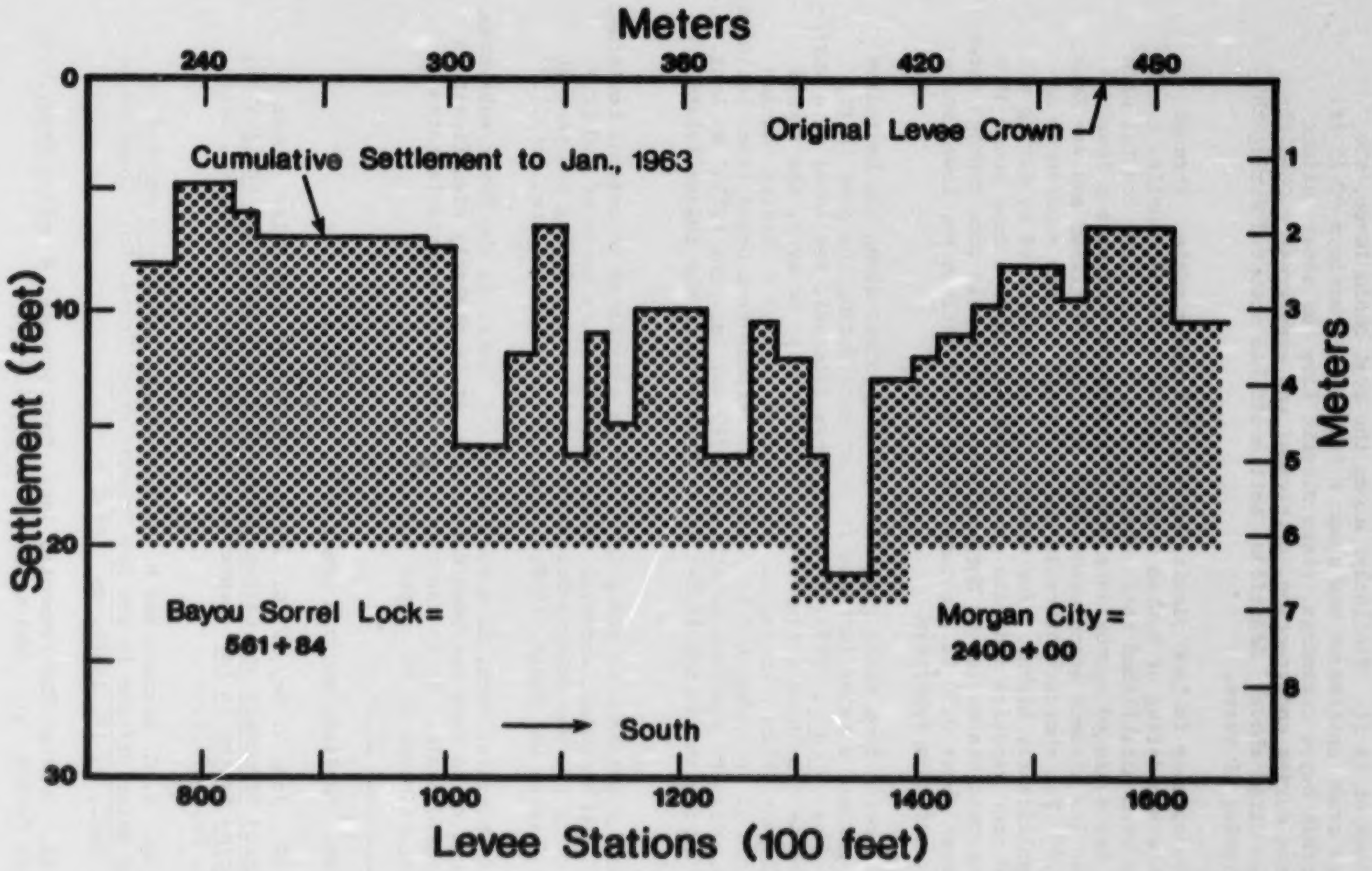

Figure 4-5. Cumulative settlement along the East Atchafalaya Basin Protection Levee (after Hebert, 1967).[47]

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[47] Kermit L. Hebert, 1967, op. cit.

a maximum of 21 ft. Similarly, along the west basin levee, the average crown settlement was about 8 ft., with a maximum of 15 ft. At certain bayou crossings, where plastic flow and shear failure occurred during construction, settlement was even greater than the figures cited above. Additional settlement has occurred during the intervening 10 years.

Subsidence is land sinking on a much broader scale. Through radio-carbon dating of buried organic deposits (peats, shells, etc.), it has been established that subsidence in the Louisiana coastal area plain has averaged approximately 0.35 ft./century since sea level reached its present stand about 4300 years ago (Gagliano and van Beek, 1970).[48] For shorter intervals and in specific areas subsidence may be significantly higher. For example, rates determined by dating of buried peat deposits indicate greater subsidence in a zone south of a line between Chalmette and Morgan City. Within this zone average rates have been about 0.50 ft./century. This would include the lower end of the Atchafalaya Subsystem.

Records from tidal gauges at several points along the Louisiana coast suggest a major increase in subsidence during the past thirty years (Day, et al., 1973).[49] During this interval, sea level on a world-wide basis has shown insignificant fluctuations; however, the record from Eugene Island, Louisiana (in Atchafalaya Bay) indicates changes at rates of more than 4.0 ft./century. Records from Grand Isle, Louisiana and an offshore platform located at 29°10' N. Lat. and 89°54' W. Long. taken during the period 1950-1970 confirm part of the Eugene Island record.

Other evidence of sharp increases in subsidence in coastal Louisiana comes from benchmark surveys. These data indicate rates of 2.0 ft./century in the New Orleans-St. Bernard Parish area during the past 20 years (Kazman and Heath, 1968;[50] Coastal Environments, Inc., 1972).[51]

Subsidence, then, is a very important factor in the lower subsystem. Although rates have not been determined, it is probably significant in the middle basin. It is doubtful, however, that measureable rates of subsidence occur in the upper basin.

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[48] Gagliano and van Beek, 1970, op. cit.

[49] John W. Day, W. G. Smith, Paul Wagner, and Wilmer Stowe, Community Structure and Carbon Budget of a Salt Marsh and Shallow Bay Estuarine System in La. (Center for Wetland Resources, L.S.U., Baton Rouge, La., 1973).

[50] R. G. Kazmann and M. M. Heath, Land Subsidence Related to Ground Water Offtake in the New Orleans Area (Trans. Gulf Coast Assoc. Geol. Soc., V. 18, 1968), pp. 108-113.

[51] Coastal Environments, Inc., Environmental Baseline Study, St. Bernard Parish, La. (Baton Rouge, 1972), 159 pp.

SECTION V

FORM, PROCESS AND ENVIRONMENT

Within each major component of the basin, characteristic environmental units can be identified. These units consist of obvious and easily definable features, such as natural levee ridges, distributary channels, lakes, etc. (Table 5-1), as well as more subtle forms which may be identified only by change in vegetation, water depth, or sediment type. Examples are brackish marsh, cypress-tupelo gum swamp, and active point bars. These units are considered as specific basin environments, recognized by their aggregate characteristics, which may be described, classified, measured, and mapped.

The environmental unit is the product of the intensity and kinds of processes active in the basin. Process is reflected in such measurable variables as sediment characteristic, geomorphic form, fauna, flora, soil type, and even human utilization. The simple truth that the form of the feature mirrors process and material is the key to interpretation, and interpretation depends largely on our understanding of form-material-process relationships and effective use of natural analogs.

Hence, environmental units are the basic elements in basin analysis. Each unit may have a wide distribution not only within the basin, but within other parts of the coastal zone as well. However, certain assemblages of these units serve to identify the major parts of the basin. Arrangements and types of environmental units typical of the basin are presented in Figure 5-1.

Environmental Complexes

Certain complexes of environmental units that are linked by processes constitute major subsystems within the basin. Active complexes include channels, levees, marine delta, and floodbasin. The channel, levee and marine delta complexes are all parts of the primary dispersal system of the Atchafalaya River and are dominated by river flow and sediment transport (Fig. 5-2). The influx of freshwater, dissolved solids, and transported sediments through these complexes represents a tremendous input of energy and materials into the basin, and consequently, the environmental units within these complexes are subject to frequent and rapid change. For the most part, these may be thought of as very active complexes.

In the upper basin, the channel-levee complex consists of a single, well-defined trunk channel bounded by mature natural levee ridges. Although the channel is still not in a poised condition, due primarily to changes in discharge and gradient which are still taking place, the channel has shown a tendency to meander and take on other characteristics of a mature alluvial valley trunk stream. Stage fluctuations are great

ENVIRONMENTAL COMPLEX	ENVIRONMENTAL UNIT	SUBENVIRONMENTAL UNIT
CHANNEL	Trunk Distributary	open channel towhead lateral bar active point bar
	Lacustrine Delta (active)	distributary bar, etc.
	Canal	
NATURAL LEVEE	Ridge Point Bar and Accretion Ridge Crevasse	
	Artificial Spoil	
FLOOD BASIN	Cross Basin Stream Drainage Stream Channel Lake Trapped Depression Natural Levee Rounded Lake Pond Abandoned Lacustrine Delta	open aquatic floating aquatic vegetated mat central and levee flank
	Swamp Bottomland Marsh	cypress cypress/tupelo gum tupelo gum willow grasses
	Agriculture Canal Canal Network Borrow Pit	
MARINE DELTA	Channels Bars Delta Front Prodelta Bay Bottom Reefs	

Table 5-1. Environmental Complexes, units, and subunits in the Atchafalaya Basin.

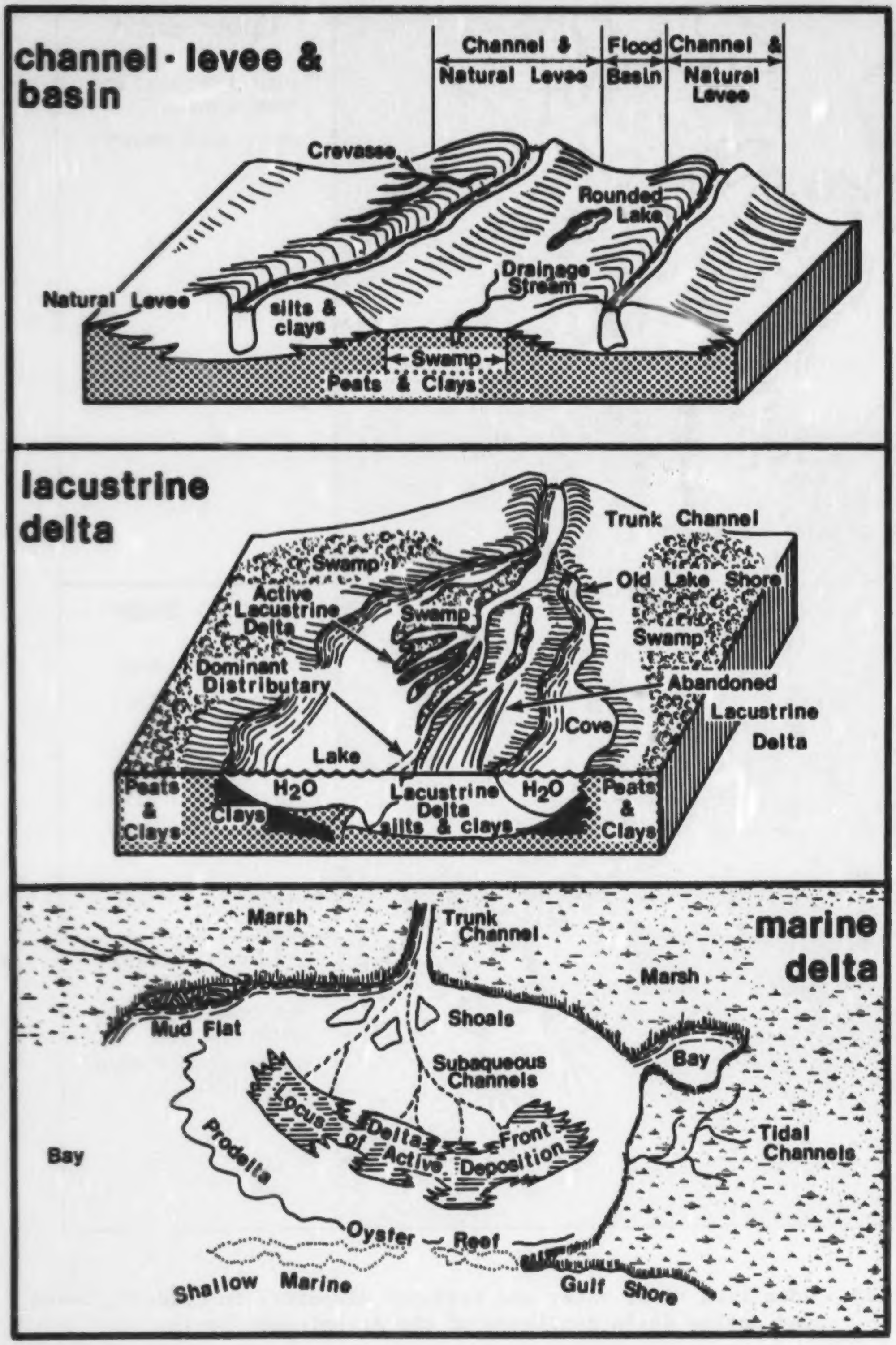
channel · levee & basin
Channel & Natural Levee
Flood Basin
Channel & Natural Levee
Crevasse
Rounded Lake
Drainage Stream
Natural Levee
silts & clays
Swamp
Peats & Clays
lacustrine delta
Trunk Channel
Swamp
Old Lake Shore
Active Lacustrine Delta
Swamp
Swamp
Dominant Distributary
Abandoned Lacustrine Delta
Cove
Lake
Peats & Clays
H_2O
Lacustrine Delta silts & clays
H_2O
Peats & Clays
Clays
Marsh
Trunk Channel
marine delta
Marsh
Mud Flat
Shoals
Subaqueous Channels
Bay
Bay
Locus of Active Delta Front Deposition
Prodelta
Tidal Channels
Oyster Reef
Shallow Marine
Gulf Shore

Figure 5-1. Arrangements and types of environmental units typical of the basin.

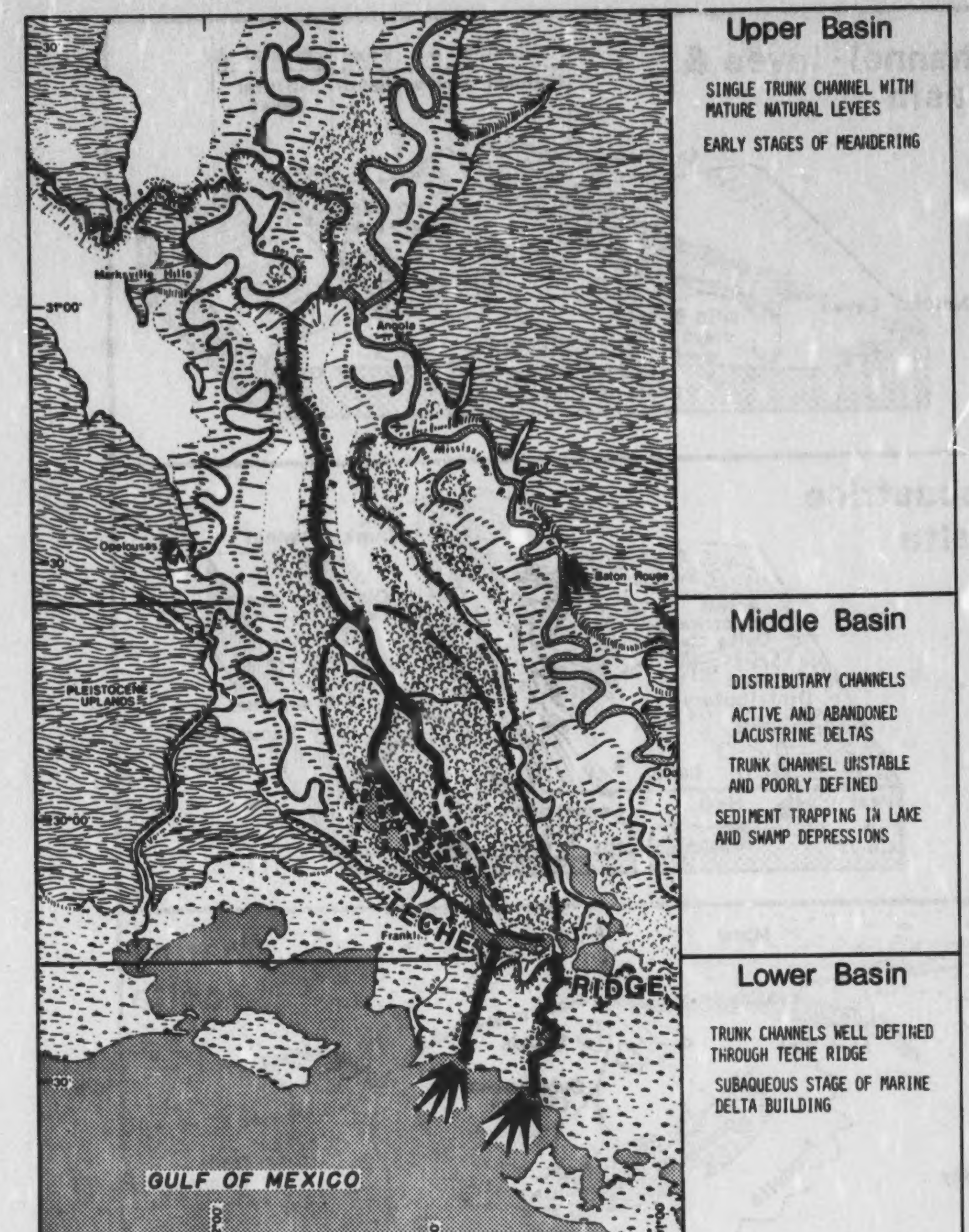
Upper Basin
SINGLE TRUNK CHANNEL WITH MATURE NATURAL LEVEES
EARLY STAGES OF MEANDERING
Middle Basin
DISTRIBUTARY CHANNELS
ACTIVE AND ABANDONED LACUSTRINE DELTAS
TRUNK CHANNEL UNSTABLE AND POORLY DEFINED
SEDIMENT TRAPPING IN LAKE AND SWAMP DEPRESSIONS
Lower Basin
TRUNK CHANNELS WELL DEFINED THROUGH TECHE RIDGE
SUBAQUEOUS STAGE OF MARINE DELTA BUILDING
30'
Marksville Hills
31°00'
Angola
Opelousas
30'
Baton Rouge
PLEISTOCENE UPLANDS
30°00'
TECHE
Franklin
RIDGE
30'
GULF OF MEXICO
92°00'
30'
91°00'

Figure 5-2. Idealized river water and sediment dispersal in channel, levee, and marine delta complexes of the Atchafalaya Basin.

and overbank flooding is infrequent. Relatively small amounts of sediment are introduced into the floodbasin areas during these periods of overtopping because of the height and width of the natural levees and the depth of the channel. For these reasons, future aggradation from river-introduced sediment in the floodbasin will be negligible and will consist primarily of clays.

In the middle basin, the trunk channel loses its identity as it enters a very large depression. As stated previously, it is this area which has undergone dramatic changes during recent historic times as the river has progressively filled a series of very large lakes and swamps. From the standpoint of sedimentary processes, the middle basin can be thought of as a great sediment trap. As the river enters this depression, the channel and levees lose their identity, and the flow and sediments of the system are no longer confined. This results in an increase in cross-sectional area and a decrease in velocity. The loss of velocity reduces the river's capacity to transport sediment. Where velocity losses occur, the stream dumps, or deposits, the coarsest sedimentary particles in transit. In the Atchafalaya, these consist of sand and silt. The new deposits quickly form bars and shoals, forcing the river into a branching pattern. In the confines of a lake, some of the branching channels may ultimately rejoin on the downbasin end of the lake, leaving great spindle-shaped areas of channels and bars. As the lake or depression becomes filled, one or two channels dominate and the others are abandoned or filled.

This process of lacustrine delta building initiates an environmental succession, changing the lake into a hummocky swamp with alternating linear ridges and depressions. Vegetation encroachment follows the deposition of sediment and new bars are quickly colonized by willows. Other hardwoods may eventually follow.

The river system regains its identity as it passes through the Teche Ridge. Here all of the river's flow, combined with local runoff from within the basin, passes through the Lower Atchafalaya and Wax Lake Outlet channels. In recent years, as the lakes of the middle basin have been largely filled, much of the transported sediment of the river is now passing through these two outlet channels. Movement of large sand waves in the channels and appreciable siltation in the Morgan City area occurred during the flood of 1973.

Since about 1950, a marine delta has started to form in Atchafalaya Bay (Garrett, *et al.*, 1969;[52] Shlemon, 1972;[53] Shlemon and Gagliano, 1972).[54] The marine delta is now in an advanced stage of subaqueous growth and several shoals emerged above water after the flood of 1973. Studies of bottom cores taken in the bay during 1973 have enabled the mapping of subenvironments associated with the new delta. As shown in Figure 5-3, a locus of active deposition associated with the delta front environment extends as a broad arc through the southern third of the bay, and a pattern of branching distributary channels is starting to develop. It is anticipated that additional shoals will soon form and become vegetated with marsh grasses. The delta front will advance progressively seaward until the bay is filled. During the next 20 years, up to 80 percent of the sediment transported by the Atchafalaya will be deposited within this bay unless the process is aborted by channel training or dredging. By 1990, the delta front should be advanced beyond the Point au Fer Reef, and the bay will be essentially filled.

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[52] B. J. Garrett, 1969, *op. cit.*

[53] Roy J. Shlemon, 1972, *op. cit.*

[54] Roy J. Shlemon and S. M. Gagliano, *Birth of a Delta: Atchafalaya Bay, La.* (24th Proc. of the IGC, sec. 6, 1972), pp. 437-441.

Environments of the floodbasin complexes are dominated by in situ processes. That is, elevations, local runoff, and water and soil chemistry are most dominant in determining the character of the environments. The effect of the river system must, however, be considered, as it will induce long term changes particularly through sedimentation, and is responsible for short term stresses related to stage variations.

In the upper basin, well-drained bottomlands predominate in the floodbasin (Fig. 5-4). Locally, small lakes and poorly drained swamps occur, but the major environmental type is the bottomland hardwood forest. Seasonally, standing water may occur from local runoff and/or overbank flooding from the Atchafalaya, but the bottomlands are usually dry through much of the year. From the standpoint of process and sediment deposition, these are passive environments. A small amount of clay precipitates may be periodically introduced as a result of overbank flooding, and peats may accumulate locally in poorly drained swamps, but, in general, aggradation is occurring only very slowly. The soils of the bottomlands are typically clays. Peats do not accumulate because of the high rate of microbial decomposition of plant litter that occurs under well-drained conditions.

Predominant environments in the floodbasin complexes of the middle basin are swamps and lakes. As shown in Figure 5-4, these complexes can be identified: two large overflow swamp areas lying east and west of the main channel of the Atchafalaya River within the floodway levees, and two isolated swamp-lake areas lying beyond the floodbasin levees, but within the natural boundaries of the basin.

The overflow swamps are, in reality, a series of pan-shaped depressions arranged in stairstep fashion on both the east and west sides of the main channel. Under natural conditions, these swamps are almost continuous, but the intrusion of the Atchafalaya and its distributaries, along with canals and levees, has segmented the swamps into smaller units. The swamps are typically bounded by levee and spoil ridges on the main channel and north sides, and are open-ended to the south. An interior drainage network directs local runoff and overbank flow water to the south. The interiors of the swamps have 2 to 3 ft. of standing water throughout the year. The levee rims are

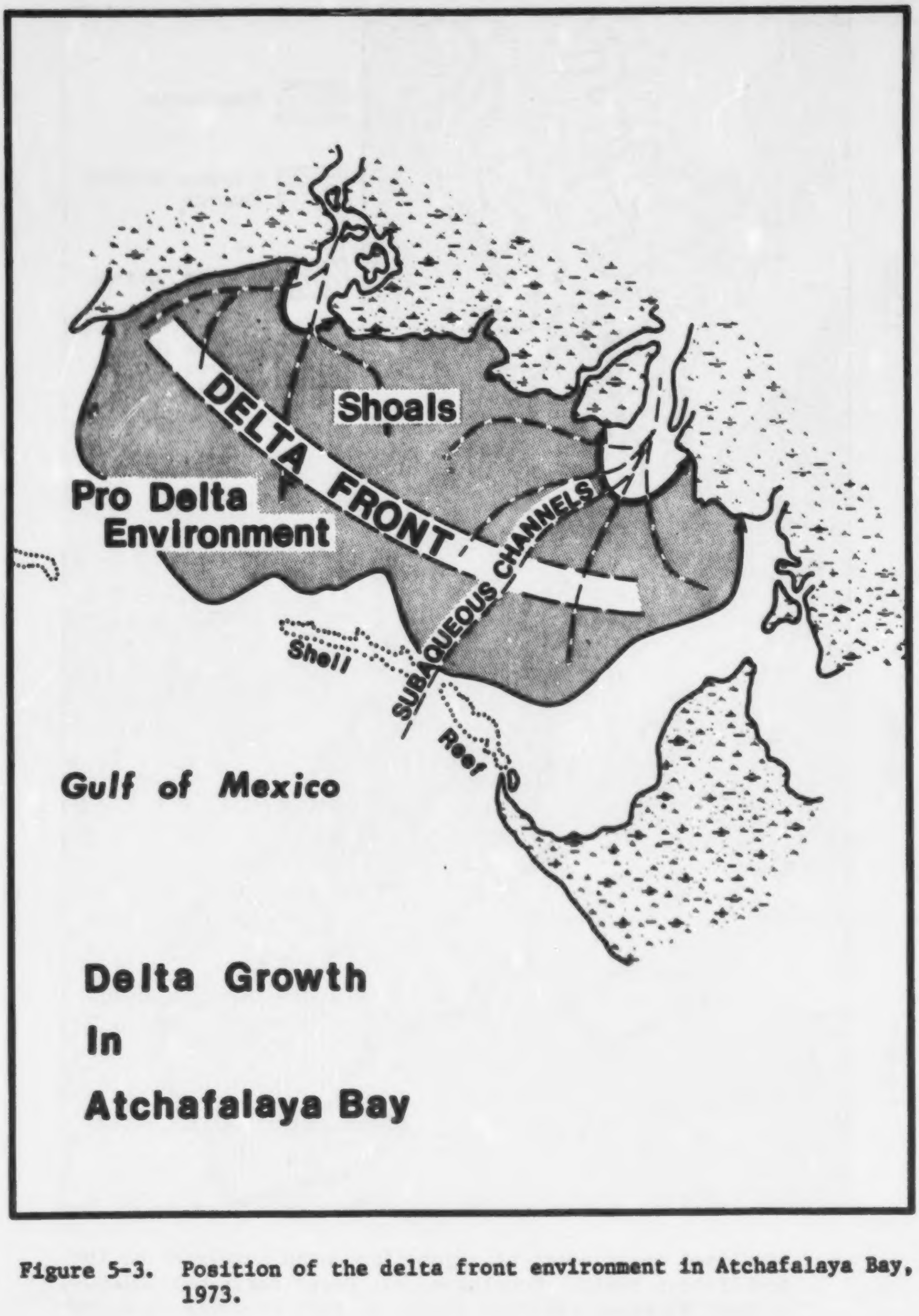
DELTA FRONT
Shoals
Pro Delta Environment
SUBAQUEOUS CHANNELS
Shell
Reef
Gulf of Mexico
Delta Growth
In
Atchafalaya Bay

Figure 5-3. Position of the delta front environment in Atchafalaya Bay, 1973.

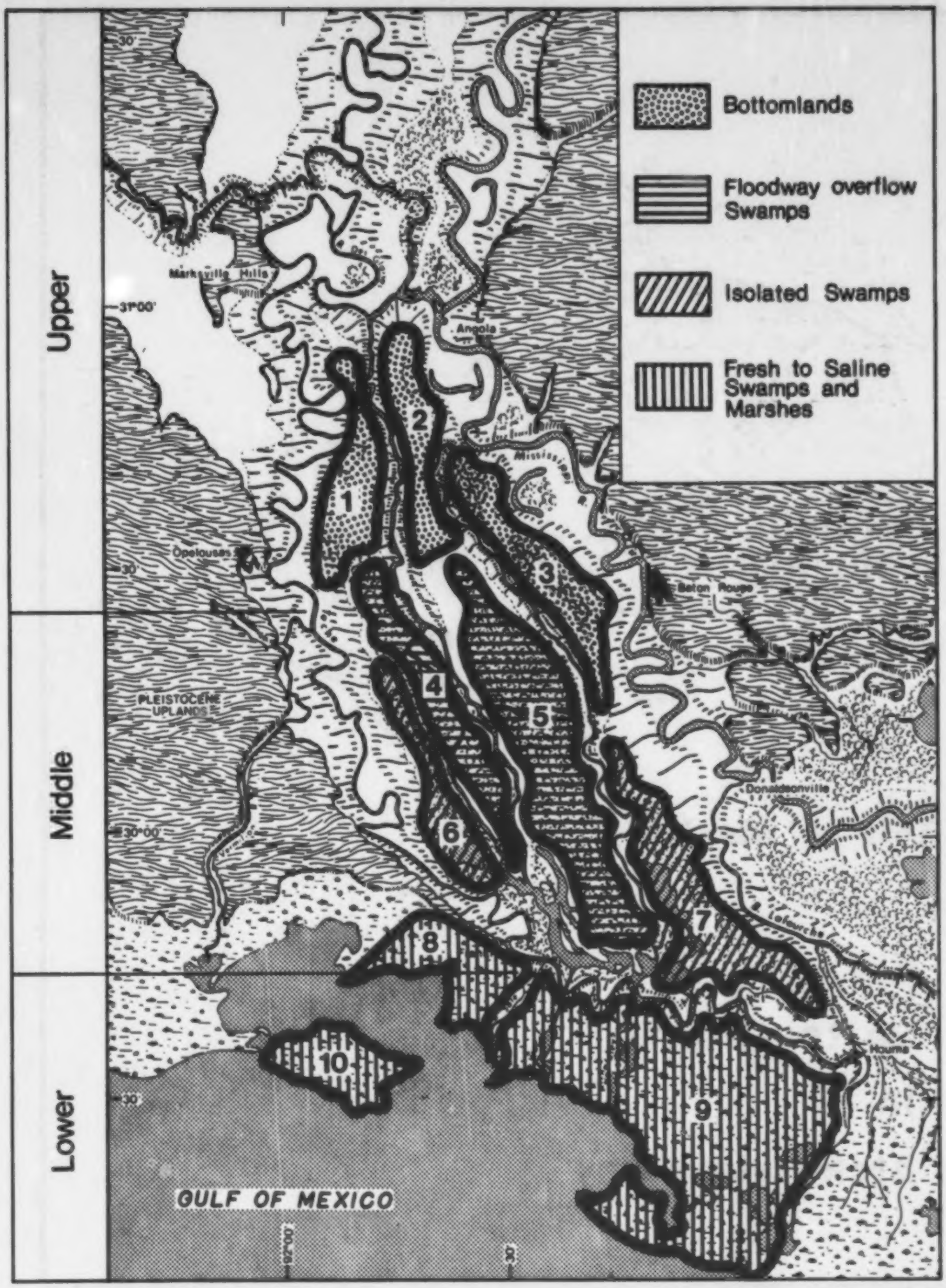
Bottomlands
Floodway overflow Swamps
Isolated Swamps
Fresh to Saline Swamps and Marshes
Upper
Middle
Lower
30'
Marksville Hills
31°00'
Angola
Opelousas
30'
Baton Rouge
PLEISTOCENE UPLANDS
Donaldsonville
30°00'
Houma
30'
GULF OF MEXICO
92°00'
30'
1
2
3
4
5
6
7
8
9
10

Figure 5-4. Idealized arrangement of major floodbasin complexes of the Atchafalaya Basin. Complexes 1-3, Upper Basin bottomlands; 4, West Floodway overflow swamp; 5, East Floodway overflow swamp; 6, Lake Fausse Point isolated swamps; 7, Verret-Palourde isolated swamps; 8-10, Lower Basin swamps and marshes.

inundated only during flood. The levee backslopes and swamp margins are dry during low stage. Vegetation is distinctly zoned from mixed hardwoods on the levees (sycamore, cottonwood, oaks, etc.) to cypress-tupelo gum in the poorly drained swamps of the central depressions. The cypress-tupelo gum represents a climax condition adjusted to the overflow and standing water regime of the swamps. The environments of these complexes are normally characterized by passive conditions of sediment deposition. Small amounts of detrital sediment are introduced during periods of overbank flooding, but it is deposited mainly in the backlevee areas and rarely reaches the central swamp. As a result of the standing water conditions in the central swamps, microbial activity is reduced, and peats may accumulate from plant litter. Peat deposits up to 20 ft. thick may be anticipated, depending on the age of the swamp. The bottoms of lakes are characterized by clayey sediments, poorly laminated and highly bioturbated by freshwater clams (predominantly Unio sp., with some Rangia cuneata).

The backlevee areas and swamp margins have clayey soils similar to those of the bottomlands of the upper basin.

Between the floodway levees and bordering levees of the natural basin are two large floodbasin complexes consisting predominantly of swamps and lakes (Fig. 5-4). Originally, these areas shared in the overbank flooding from the Atcnafalaya River, but since construction of the floodway levees, they constitute distinct sub-basins. Hydrology and water chemistry are related entirely to local runoff from within the sub-basins and bordering natural levee ridges. Although the origin, configuration, and forms of these isolated swamp complexes are similar to those of the floodway overflow swamps, the approach to management must be somewhat different because of the source of freshwater and sediment input. In this regard, these complexes are characterized by very passive conditions. Small amounts of detrital sediment are introduced, and these come only from local streams and canals draining the bordering natural levees and swamps themselves. Remnants of abandoned lacustrine deltas in Lake Fausse Point attest to the fact that distributaries of the Atchafalaya were actively depositing sediment in the western isolated swamp complex before construction of the West Floodbasin Levee and the Lake Fausse Point Cutoff. These works effectively divorce the complex from Atchafalaya input.

The drainage of both the east and west isolated swamp complexes is restricted at the southern end by the Teche Ridge. On the west side drainage exists through the Charenton floodgate, and on the east side, the major outlet is through Bayous Boeuf, Chene, and the lower end of Lake Palourde.

Because of their proximity to large agricultural areas along the bordering natural levees and the sluggish internal drainage network, pollution from pesticides and other agricultural chemicals may be a serious problem. This is of particular significance in the eastern complex because Morgan City draws its freshwater supply from Lake Palourde.

These sub-basins may have a higher percentage of surface area occupied by freshwater lakes than any other part of the basin. These lakes are very shallow (2-6 ft.) with muddy bottoms and poorly defined shorelines. In most places, the open water of the lake merges with bordering swamp. In general, the areas of the lakes are presently expanding in size.

Extensive swamps and fresh to saline marshes characterize the Atchafalaya floodbasin complexes south of the Teche Ridge. These marshes bordering Atchafalaya and East and West Cote Blanche Bays were initially established during previous episodes of delta building several thousand years ago. The marshland surfaces have persisted in spite of erosion and subsidence largely because of the ability of the marsh and swamp vegetation to build up peat deposits and vegetation mats to compensate for land sinking. Coleman (1966)[55] and Frazier (1967)[56] have documented the extensive distribution of peat deposits in part of the area.

Vegetation distributions in these floodbasin complexes of the lower end of the Atchafalaya system are largely controlled by salinity gradients. Although the large discharge of the Atchafalaya does keep salinities low during most of the year, mid-bay salinities of 3-4 ppt do occur during low stage. Salinities of 0.3 ppt occur at Morgan City during low stage.

The marshes and swamps have an intricate tidal-drainage network adjusted to local runoff and tidal conditions. This network has been considerably modified by canals and levees in many parts of the area. Prior to the present episode of marine delta building by the Atchafalaya, the lower end of the basin was in an advanced stage of delta deterioration. Land loss was occurring, largely through shoreline erosion and swamp and marsh deterioration. Ironically, even though the marine delta is presently receiving large volumes of sediment, the trend of deterioration has not yet been noticably reversed. Shoreline erosion around the bay margins continues. However, it can be anticipated that as soon as the marine delta of the Atchafalaya passes from the subaqueous to the subaerial stage, this trend will be reversed. From that point on, the present marshes will become landlocked and will become progressively fresher in character.

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[55] James M. Coleman, 1966, op. cit.

[56] D. E. Frazier, 1967, op. cit.

SECTION VI

ENVIRONMENTAL SUCCESSION

Even to a casual observer it becomes apparent that in many areas the basin is changing at a rapid rate. As discussed, this may be attributed to both natural processes and changes that occur as a result of human activities. The latter affect the basin environment directly through, for example, reclamation, or indirectly through a redirection of natural processes. Recognizing that these changes substantially affect the occurrence and distribution of the various environments and thereby the future use of the basin, it is extremely important to direct attention to what is occurring at a given place through time. That is, the determination of trends of change is a principal requirement for defining management guidelines.

Succession Model

The ability to predict changes and to develop guidelines that will direct changes toward optimum conditions for use depends on the extent to which it is possible to develop a model for evaluating environmental succession. Figure 6-1 illustrates the use of such a model conceptually. Selecting a fixed area and using geologic data, historic information, and present conditions, types and rates of change that are occurring in that area as a result of natural processes can be established. Extrapolation of this change will then yield a future condition. This is the basic approach for defining and measuring geological succession and for predicting changes that result from this succession if allowed to continue uninterrupted.

In many cases, however, the natural succession may be disrupted by human impact so that deviation occurs. By measuring this deviation in historic times through the use of maps and other historic documents, it becomes feasible to predict the future condition of the unit or block for a modified succession resulting from human impact, as in Block C, Fig. 6-1. The difference between the natural succession and the modified condition is a measure of human impact.

Further, it may be assumed that the rate of human impact need not remain constant, but is likely to increase. Projection of this rate will drive the future condition further away from natural succession (Block D). When the natural succession is thought of as representing a kind of balance and modified succession representing some degree of imbalance, the condition associated with Block D represents an environment that has moved farther toward imbalance. These trends toward imbalance can only be prevented or remedied through management of the system. With management considered, a compromise between natural succession and the condition resulting from undirected and uncoordinated human modification is possible. The objective of management, then, is the block shown as B in Figure 6-1.

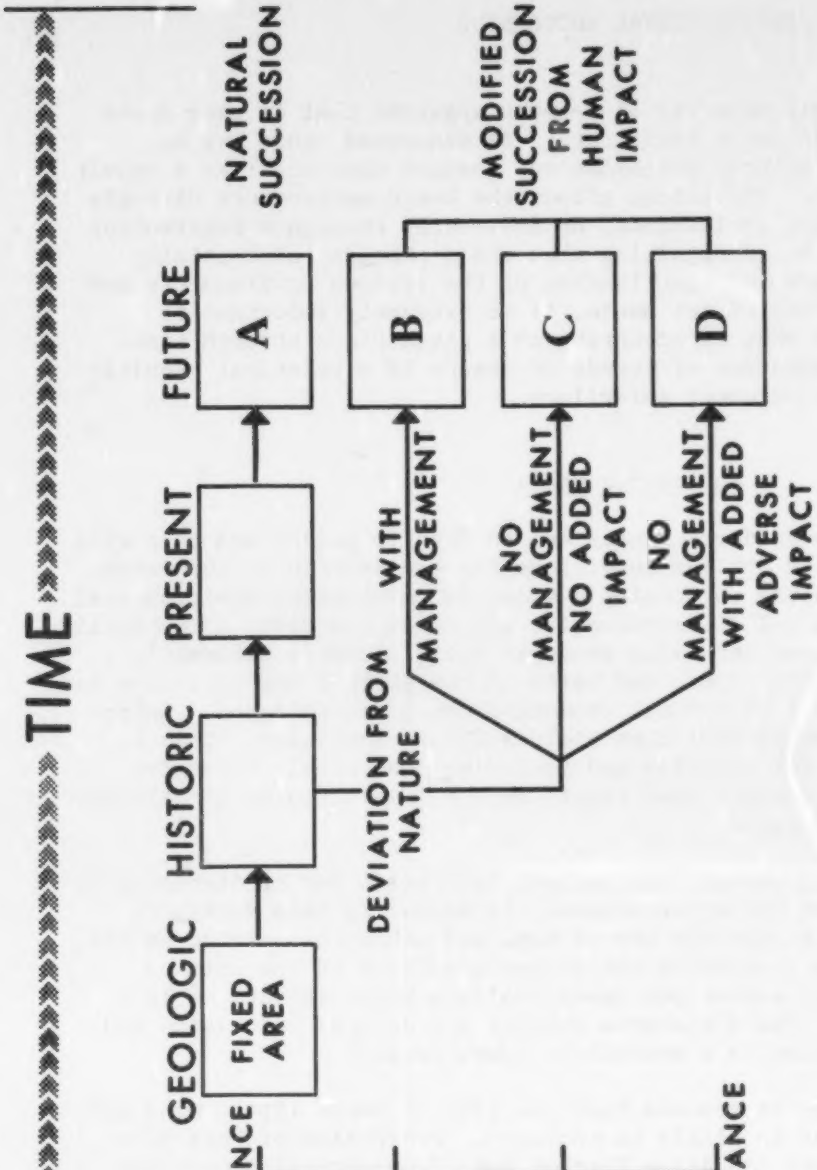
TIME
BALANCE
IMBALANCE
GEOLOGIC
HISTORIC
PRESENT
FUTURE
FIXED AREA
A
B
C
D
NATURAL SUCCESSION
MODIFIED SUCCESSION FROM HUMAN IMPACT
DEVIATION FROM NATURE
WITH MANAGEMENT
NO MANAGEMENT NO ADDED IMPACT
NO MANAGEMENT WITH ADDED ADVERSE IMPACT

Figure 6-1. Conceptual model of environmental succession.

Measuring Succession

Most of our knowledge concerning natural succession in the basin pertains to the area as a whole and deals with the change from a lacustrine to a wetland environment. In particular, the work of Fisk (1952)[57] documents this change where extensive lakes are progressively filled in as a result of lacustrine delta building (Fig. 3-5,6,7,8,9). As pointed out earlier, this process has now advanced to a stage in which a new type of change becomes increasingly dominant; that whereby the wetland is gradually replaced by a more terrestrial environment. Increasingly, we also find a deviation from natural succession as a result of human impact.

Sequential aerial photographs have proved to be invaluable in measuring succession and evaluation of changes of various basin environments. A representative sample for the basin succession was determined for each of the unit areas along U. S. Army Corps of Engineers survey lines (Ranges 6, 12, 17, 21, see Appendix C, Plate 9). Each unit area comprised a square cell of 10^8 $ft.^2$ corresponding to the data base grid. Using aerial photographs taken in 1940, 1952, and 1969, the environments shown in Table 5-1 were delineated within each cell for each year of photo coverage. The area occupied by each of the environments was then determined using a Calmagraphic Digitizer, Model III.

To illustrate the procedure, changes in the occurrence and extent of certain environments are illustrated for cell number 664, survey line 17, in Figures 6-2A, B, and C. The most salient change in this cell is the conversion of open lakes and associated aquatic vegetation to a swamp environment. Another natural change involves the shift from a natural levee to a swamp environment, associated with channel abandonment. With regard to human impact, the spoil deposit on the natural levee represents a man-induced change.

As a sample of broader areas of the basin, the results obtained from computation of surface area for each environment for each cell may be totalled over the entire range line. These totals are presented for each of the selected years as a percentage of the total area comprised by the cells along a particular survey line (Figs. 6-3 through 6-5).

Along survey line number 6 (Fig. 6-3) through the management units Bayou Fordoche, Bayou des Glaises, and Bear Bayou, the most significant trend is an increase in area of the natural levee environment from 20 to 30 percent, at the expense of the swamp environment. The latter is seen to occupy only 52 percent of the sample area in 1969, whereas it represented 65 percent of the area in 1940.

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[57] H. N. Fisk, 1952, op. cit.

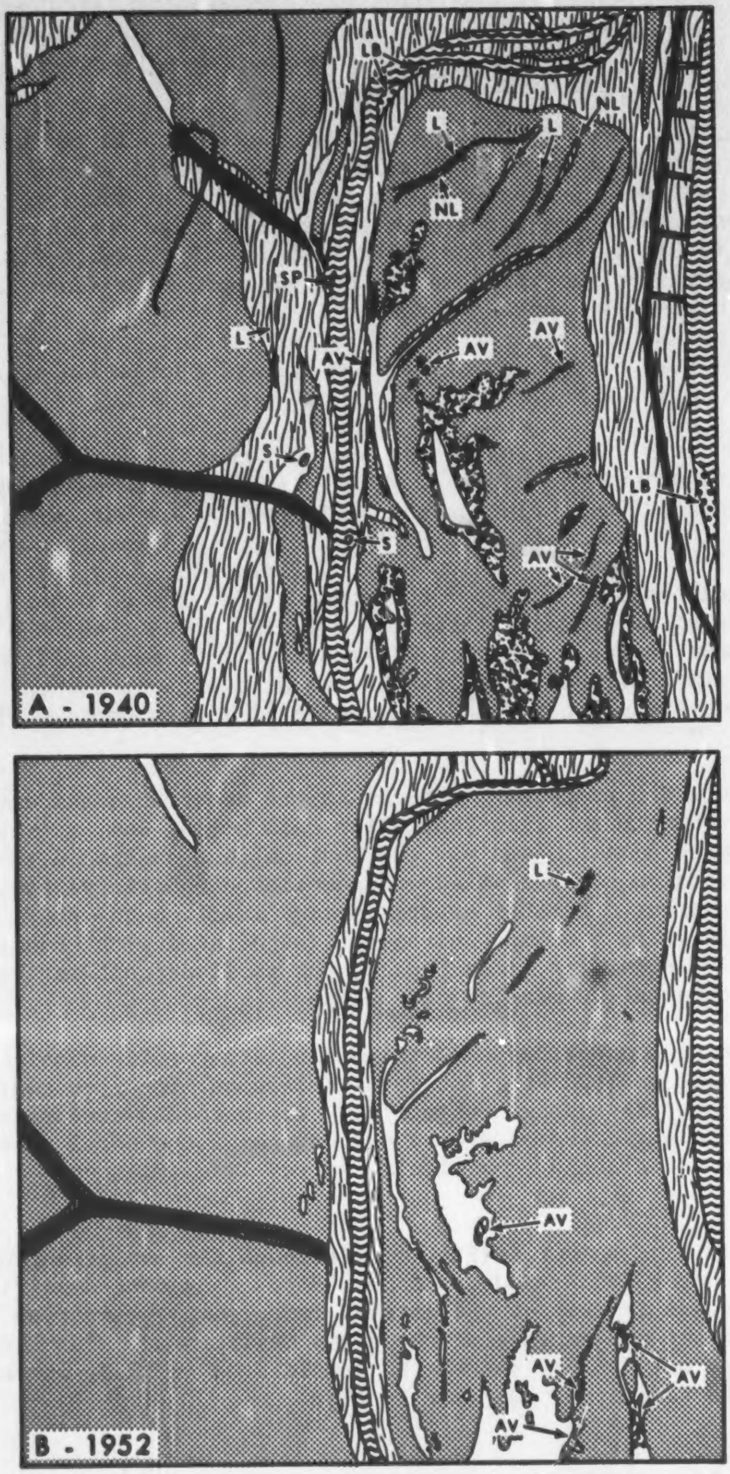
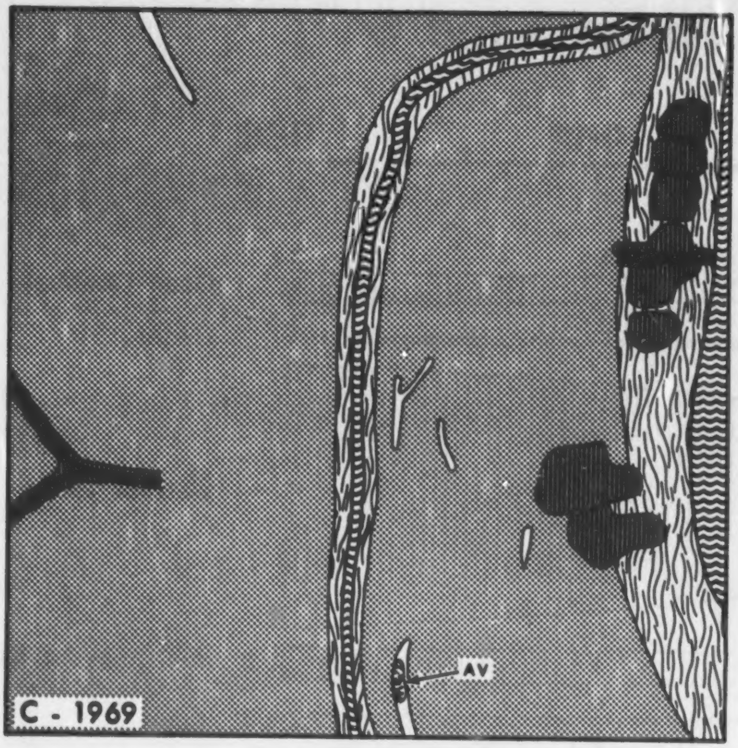

LB
L
L
NL
NL
SP
L
AV
AV
AV
S
S
LB
AV
A - 1940
L
AV
AV
AV
AV
B - 1952

Figure 6-2. Environmental interpretation of sequential aerial photographs. A-C show changes which occurred in cell number 664, survey line 17, in 1940, 1952, and 1969. The percent surface area for each environmental unit is shown for each year of coverage.



		% SURFACE AREA		
		1940	1952	1969
NL	NATURAL LEVEE	28.9	8.9	13.9
NC	NATURAL CHANNELS	5.0	3.7	3.9
ML	MANMADE LEVEE	0.8	0.4	0.0
C	MANMADE CHANNELS (CANALS)	0.5	0.5	0.5
L	LAKES	2.7	4.1	0.7
SP	SPOIL	1.0	1.0	4.1
AV	AQUATIC VEGETATION	4.6	0.3	0.0
S	SWAMP	56.2	81.1	76.9
LB	LATERAL BAR	0.3	0.0	0.0

Total cell area = 3.587 miles^2 or 2,295.68 acres

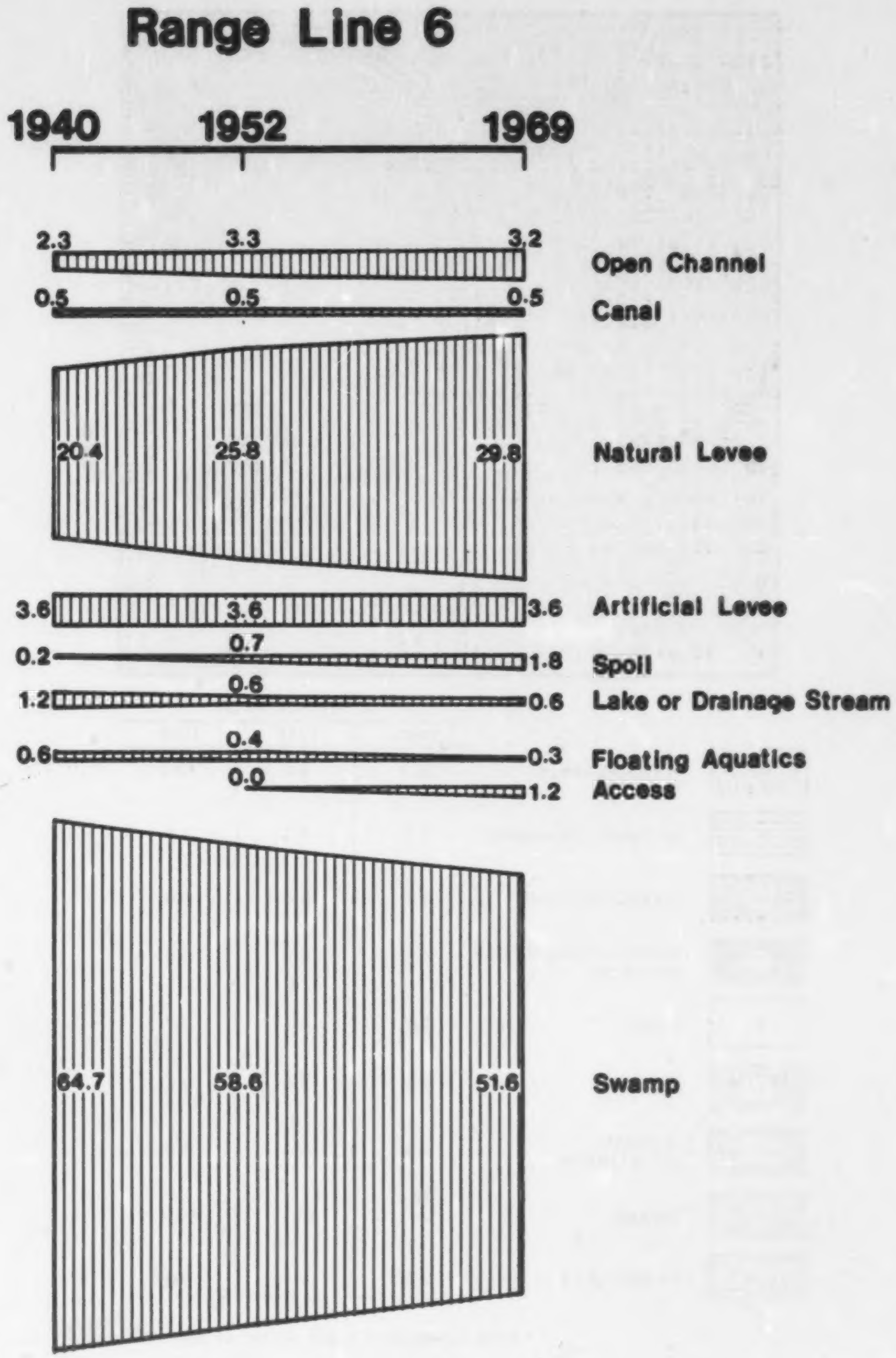


Figure 6-3. Graph showing percent relationship of surface area change per environment from 1940-1952 to 1969, Range line 6.

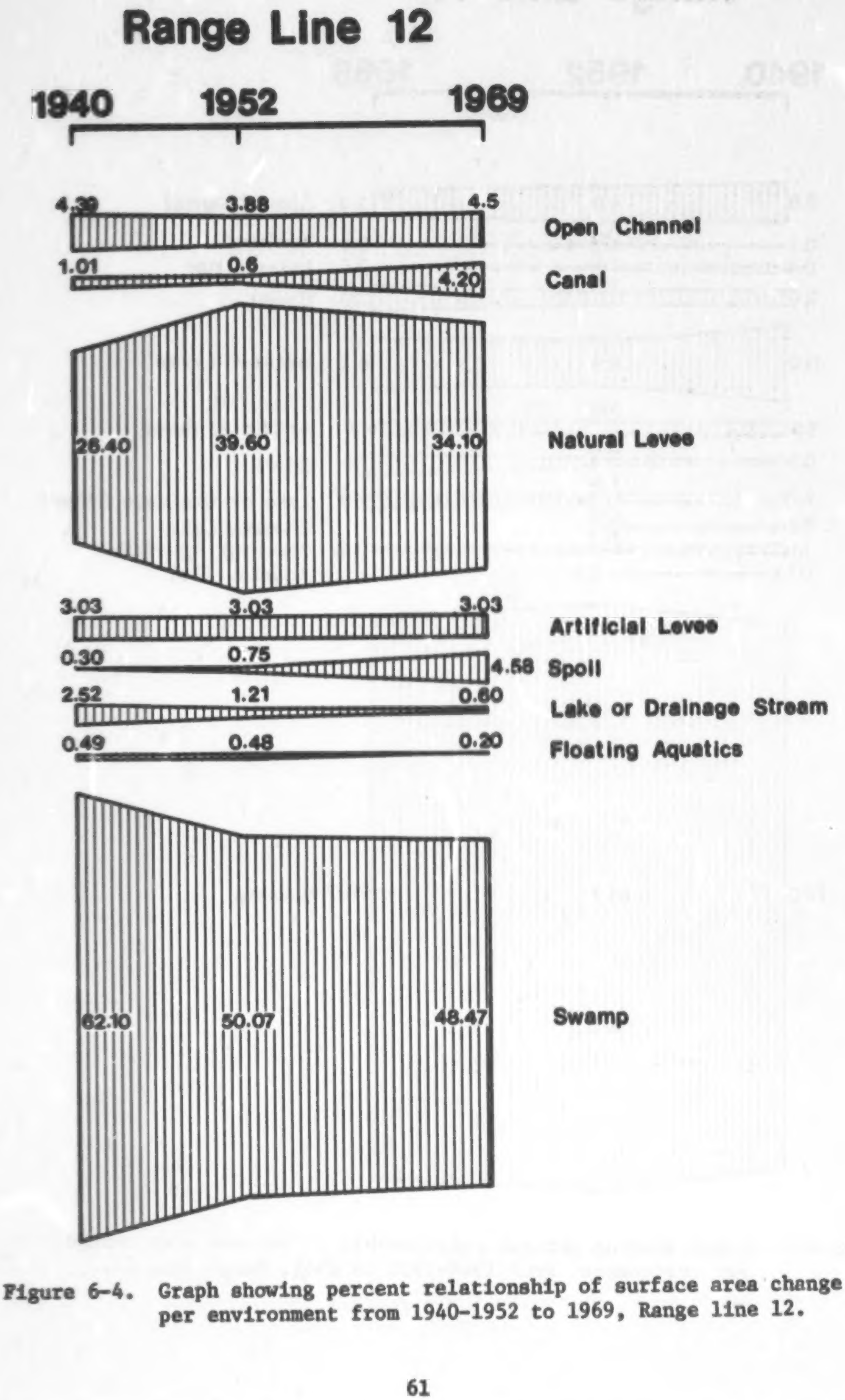


Figure 6-4. Graph showing percent relationship of surface area change per environment from 1940-1952 to 1969, Range line 12.

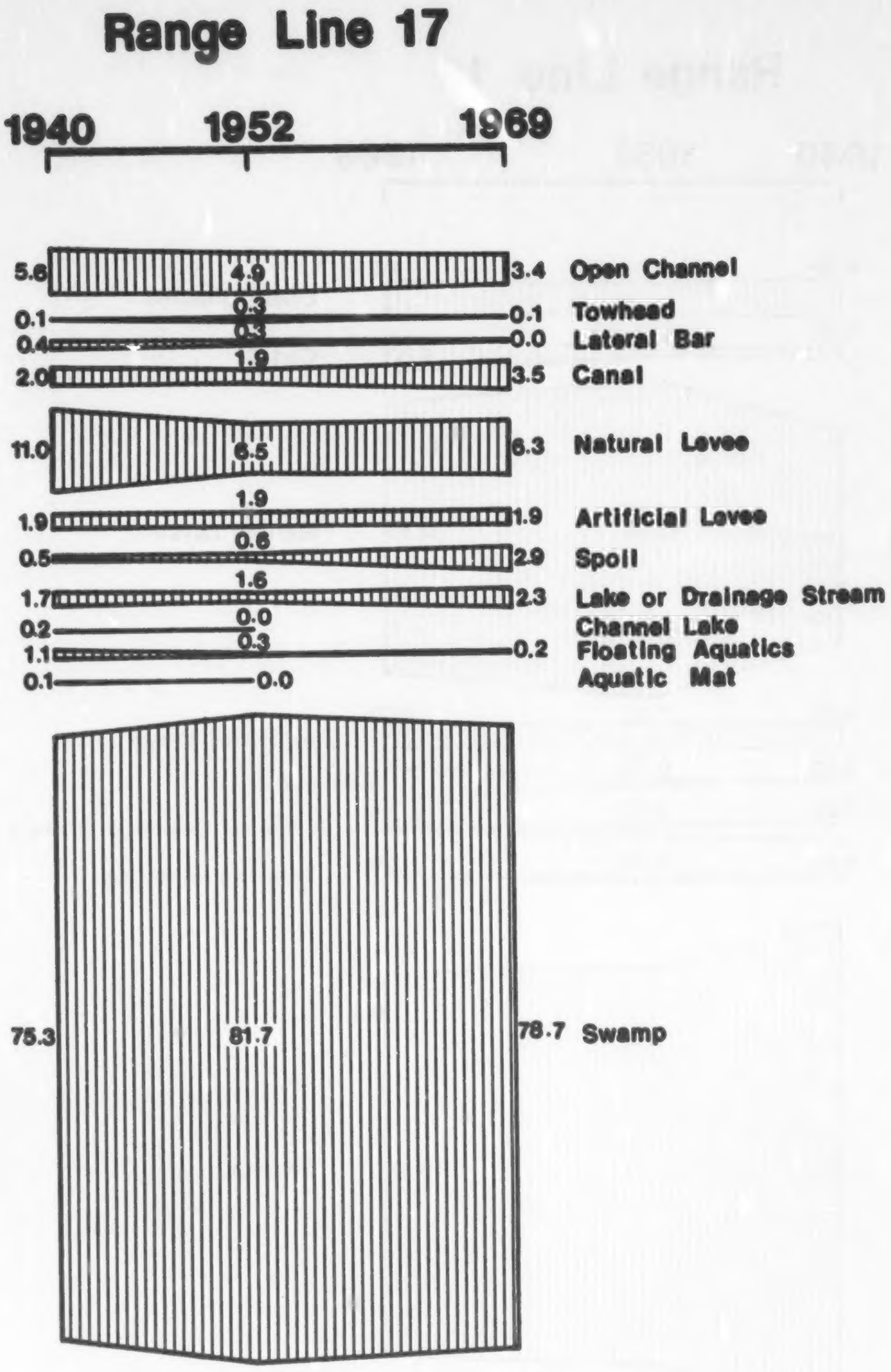


Figure 6-5. Graph showing percent relationship of surface area change per environment from 1940-1952 to 1969, Range line 17.

Changes along range line 12 (Fig. 6-4) through the Cocodrie Swamp and Pigeon Bay Management Units appeared most rapid during the period 1940-1952. Natural levee ridges widened at the expense of adjacent swamp. Subsequent changes relate mainly to deposition of spoil and canal dredgings.

In contrast to other parts of the basin, the area comprised by the upper part of Buffalo Cove and by the Flat Lake Management Unit appears to have remained rather stable in terms of overall occurrence and extent of the various environments. Although minor changes have occurred along survey line 17 (Fig. 6-5), the general picture is one of stability, however easily this condition may be disrupted. Most change pertains to the natural levee and channel environment associated with channel abandonment or closure and with spoil deposition.

The most drastic changes were found along survey line 21 (Fig. 6-6) which extends across the Upper Belle River and Six Mile Lake Management Units. Changes relate predominatly to development of a lacustrine delta in Grand Lake in the Six Mile Lake Management Unit. As a result of this, the lake environment is lost and replaced by a combination of lacustrine delta and open channel environments. The change from lake to channel evolves as a result of deposition by which the cross-sectional area is reduced and flow velocities increase.

A clear result of human impact is illustrated also in this area by the increase in canal associated spoil area. These relate primarily to the development of an oil and gas field in the Upper Belle River unit, the West Lake Verret field.

As an indication of succession in a larger area, the results obtained from the four individual samples along the four survey lines can be combined. This yields the diagram shown in Figure 6-7. The most salient trend for the basin area confined between the floodway guide levees and U. S. Highway 190 is seen to be a decrease in the extent of the swamp environment. One notices a rather steady decline from 67.7 percent in 1940 to 59.7 percent in 1969, or an annual decline of nearly 0.3 percent. This may seem small, but assuming the sample to be representative, the value represents an annual loss of 2.5 mi^2 of wetland.

Hypsometric Curves

To a large extent, environmental succession in the basin is directly related to changes in average duration and depth of annual submergence. This, in turn, evolves from the changes in surface elevation as a result of progradational and aggradational processes. Surface elevation, therefore, is an important ecological parameter, and it can be used to characterize a given area. Furthermore, the spatial and temporal variation in elevation characteristics can be analyzed and provide a measure of environmental succession.

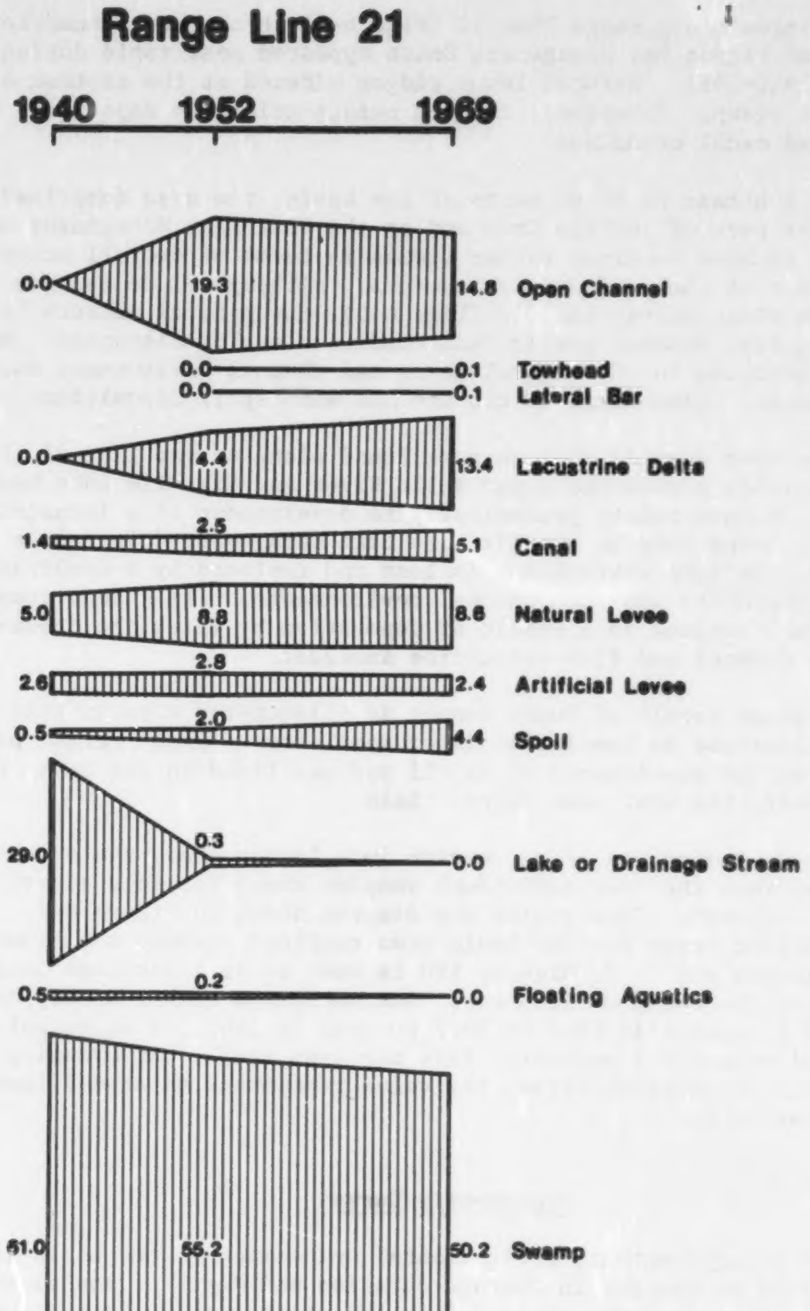


Figure 6-6. Graph showing percent relationship of surface area change per environment from 1940-1952 to 1969, Range line 21.

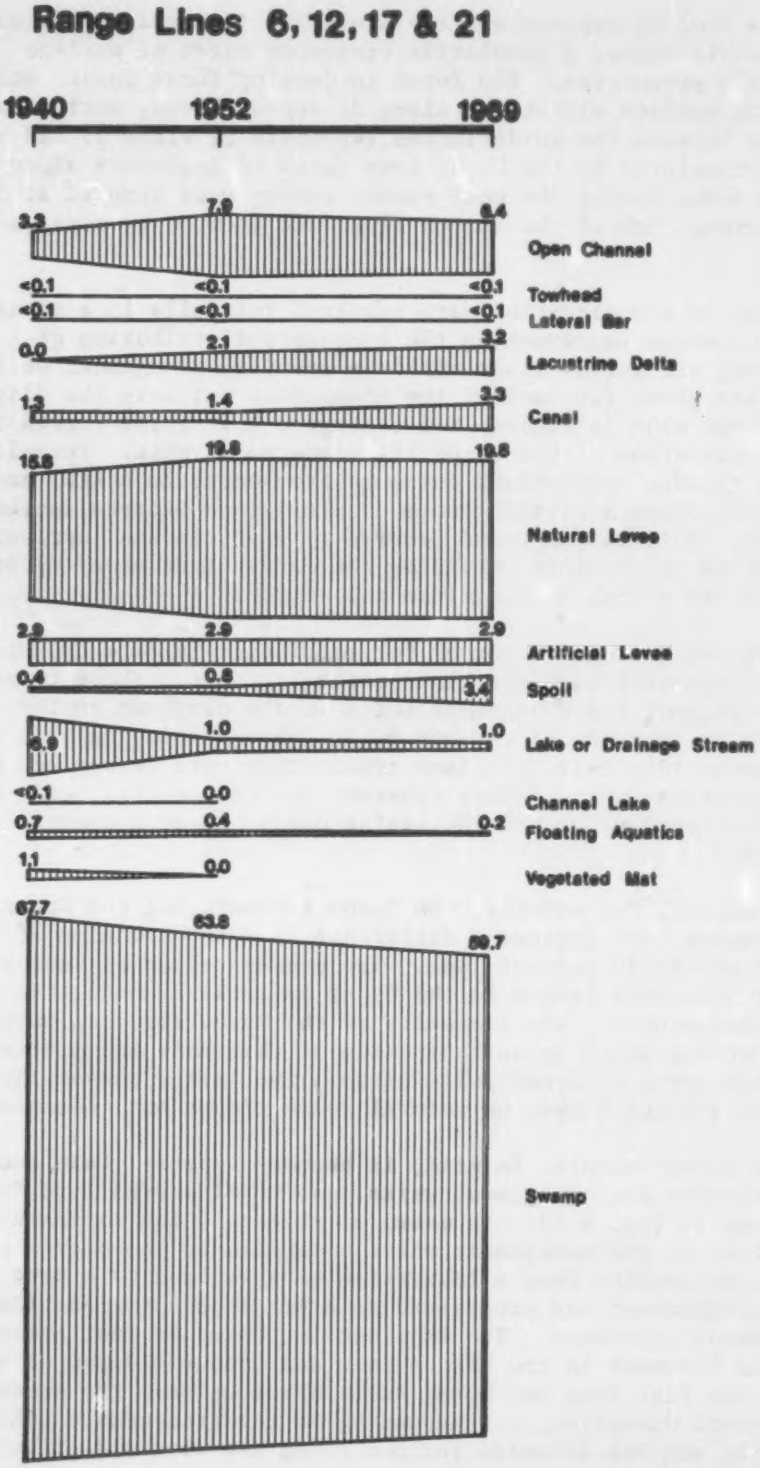


Figure 6-7. Summary graph showing percent relationship of surface area change per environment from 1940-1952 to 1969, Range lines 6, 12, 17, and 21.

The means used to express surface elevation in a meaningful way is the hypsometric curve, a cumulative frequency curve of surface elevations for a given area. The input to develop these curves was provided by the surface elevations along 31 survey lines, most of which span the basin between the guide levees (Appendix C, Plate 9) and have been surveyed regularly by the U. S. Army Corps of Engineers since 1932. Elevations recorded during the most recent survey were sampled at 1000-ft intervals along each of the survey lines and grouped by management unit.

Processing of the elevation data resulted initially in a series of hypsometric curves representing the frequency distribution of elevations along all survey lines within a specific management unit. These curves are shown for each of the management units in the diagrams on the right-hand side in Figures 6-8 through 6-18. These curves reveal the change in elevation within a specific management unit. Invariably they show two trends: elevations decrease from north to south, and in southward direction a certain range of elevations becomes increasingly dominant. This latter trend becomes apparent in the increasing development of two nickpoints, dividing the curves into steep upper and lower segments and a less inclined central segment.

Combining the individual curves for each unit yields a hypsometric curve that is representative for that particular unit. These curves are shown for each of the management units in the diagrams on the left-hand side in Figures 6-8 through 6-18. When displaying this data in summary, as in Fig. 6-19, the same trends that were recognized within individual management units become apparent for the central basin as a whole: a southward slope and increasing dominance of a specific elevation range.

When comparing, for example, the Bayou Fordoche and the Upper Belle River curves, one notices a difference in mean elevation of 9.6 ft as identified at the 50 percent line. The concentration of certain elevations is also much larger in the Upper Belle River unit than in the Bayou Fordoche unit. The linearity of the Bayou Fordoche curve reflects the strong north to south incline of this unit and contrasts with the broken curve of Upper Belle River. The latter curve illustrates a nearly level surface broken by natural levee ridges and channels.

With the above examples in mind, it becomes apparent that the curves, and thereby the management units, can be clustered into four groups as shown in Fig. 6-19. In essence, this grouping represents a classification of the management units according to the degree to which natural succession from a lacustrine to a wetland to a more terrestrial environment has progressed as a result of progradational and aggradational processes. The implication, then, is that succession has progressed furthest in the Warner Lake and Cocodrie Swamp units, and least in the Flat Lake and Upper Belle River units. The process has a north-south direction, corresponding to the progressive filling from the north, and has advanced further along the west side than along the east side of the central basin.

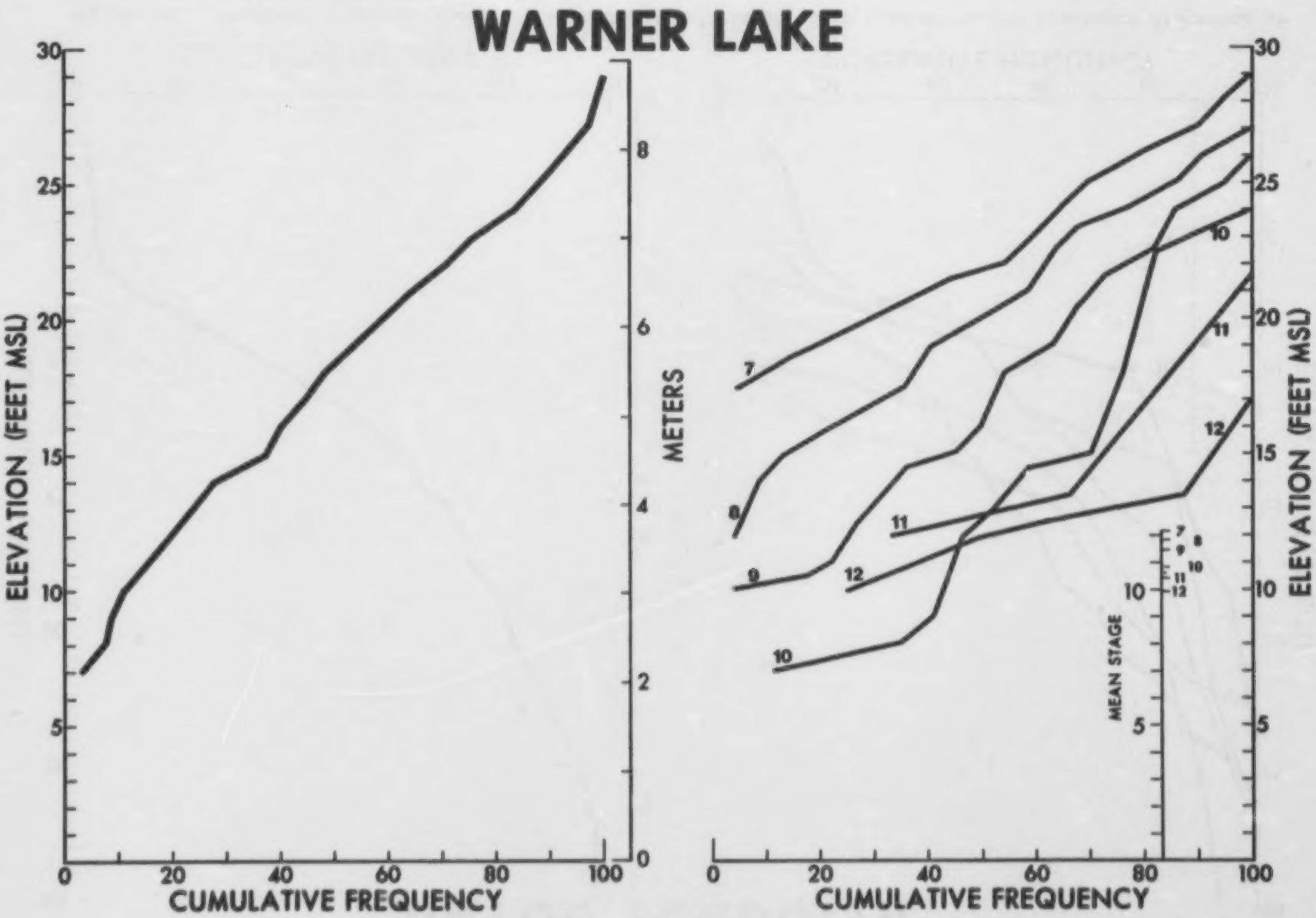


Figure 6-8. Hypsometric curves showing combined and individual range line elevation frequency distribution for Warner Lake Management Unit.

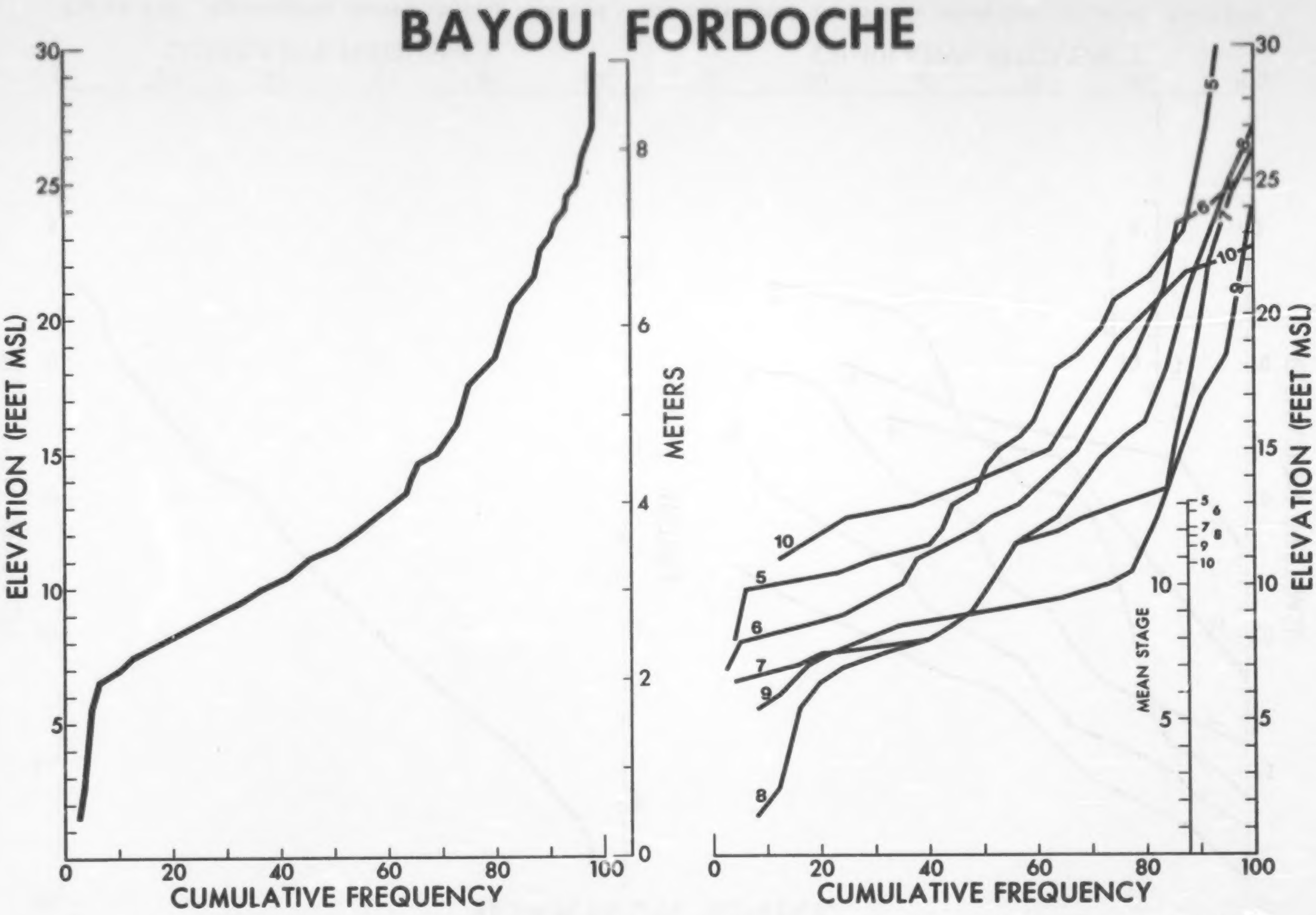


Figure 6-9. Hypsometric curves showing combined and individual range line elevation frequency distribution for Bayou Fordoche Management Unit.

COCODRIE SWAMP

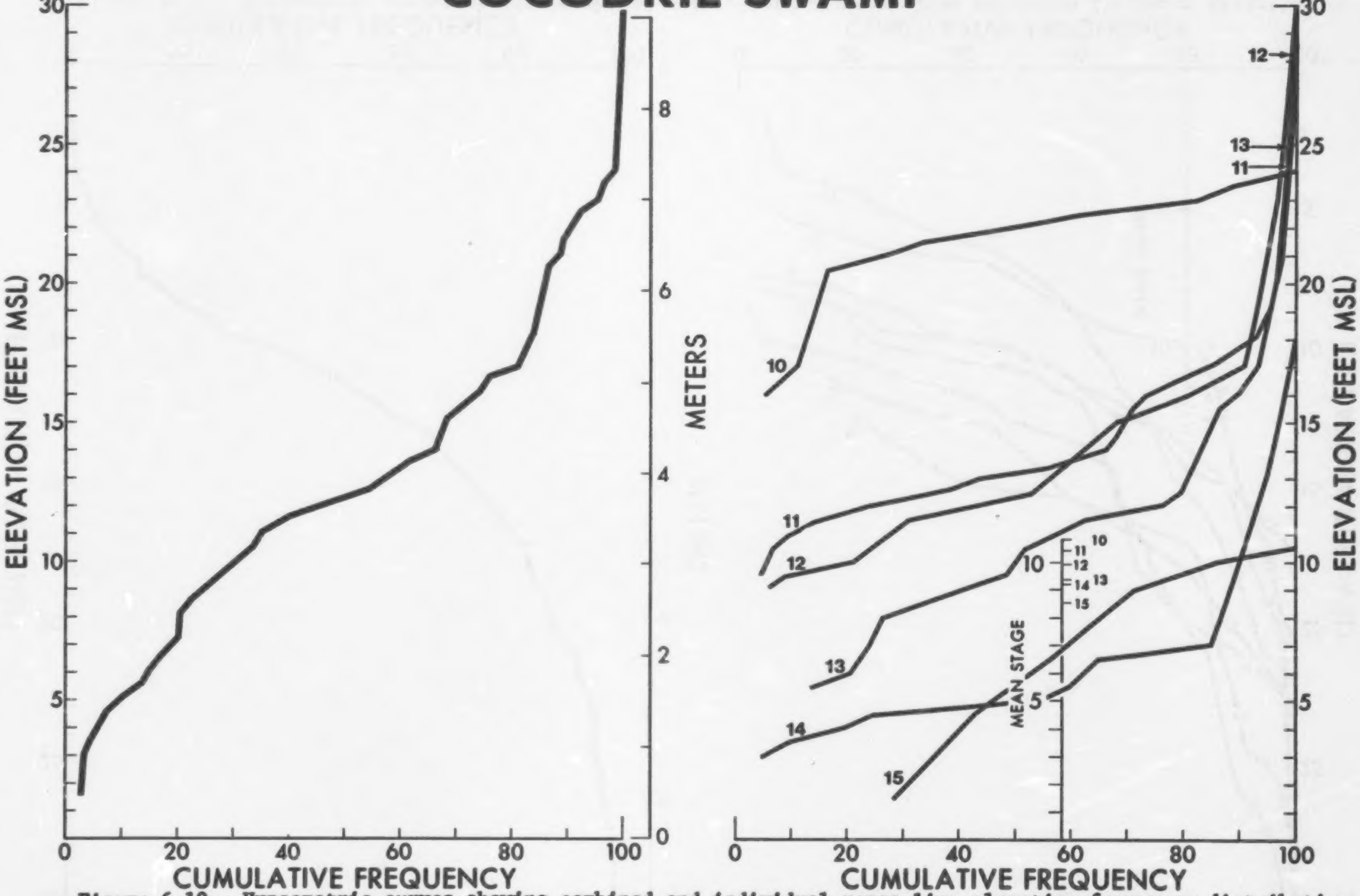


Figure 6-10. Hypsometric curves showing combined and individual range line elevation frequency distribution for Cocodrie Swamp Management Unit.

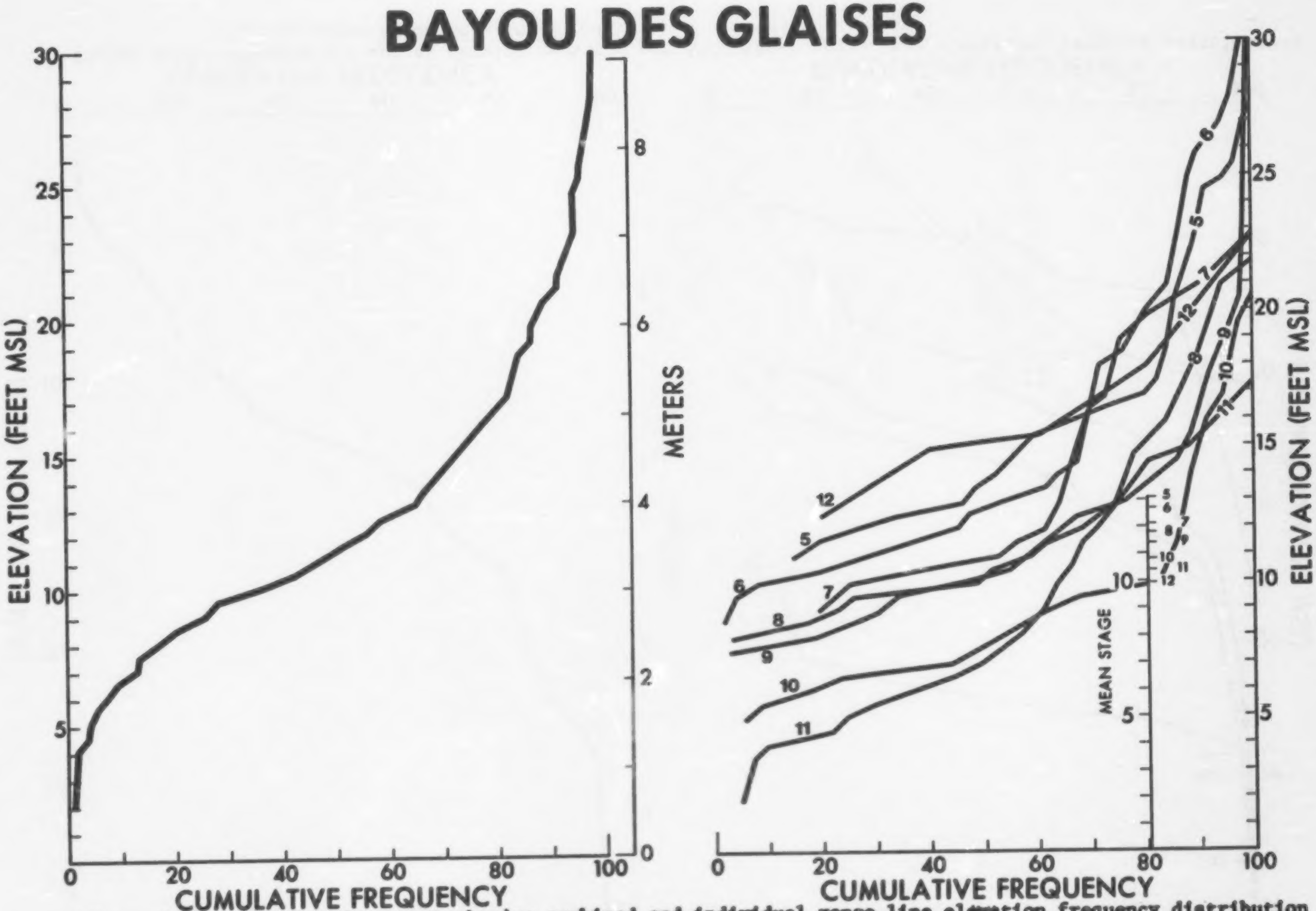


Figure 6-11. Hypsometric curves showing combined and individual range line elevation frequency distribution for Bayou des Glaises Management Unit.

BEAU BAYOU

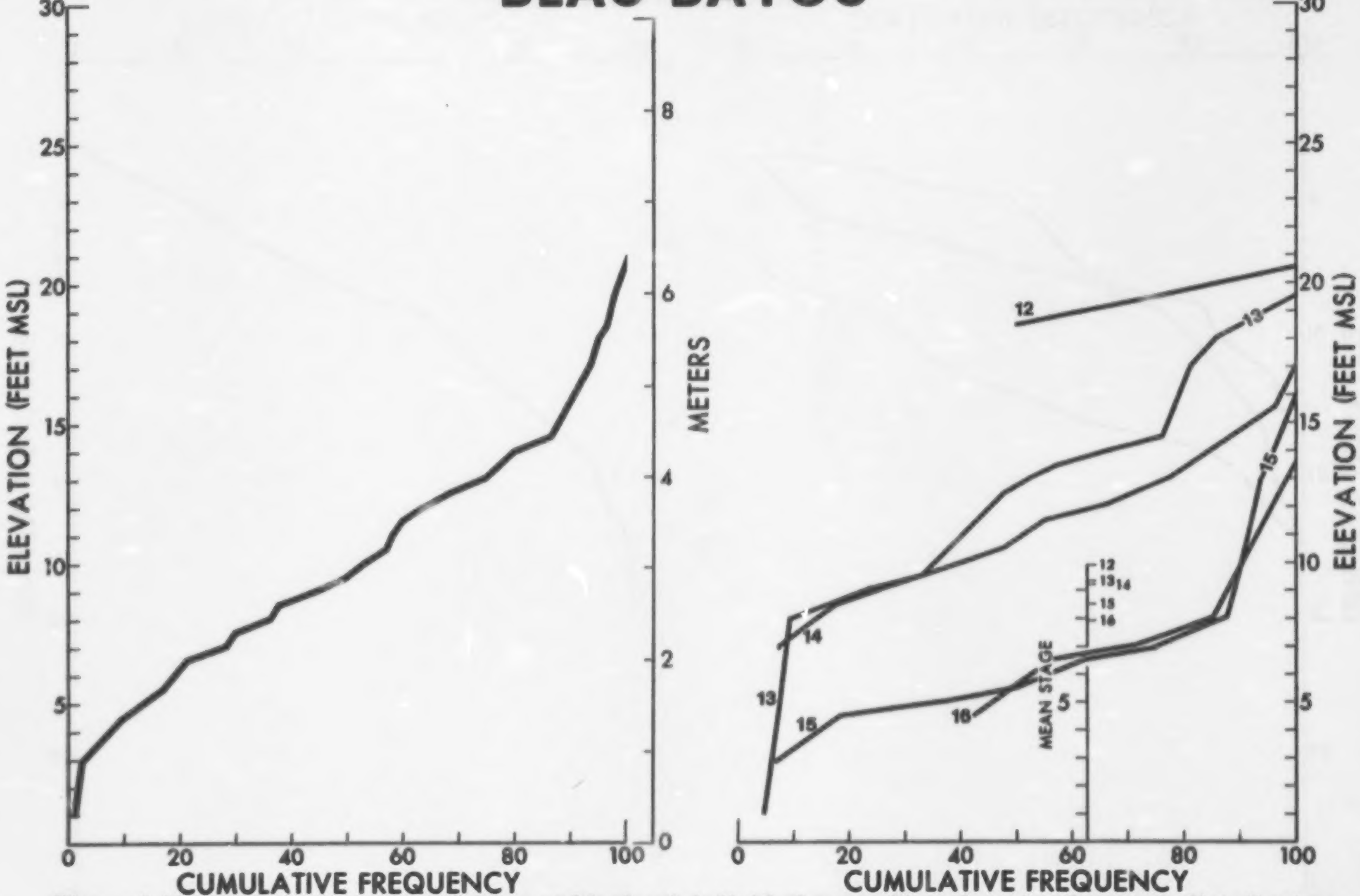


Figure 6-12. Hypsometric curves showing combined and individual range line elevation frequency distribution for Beau Bayou Management Unit.

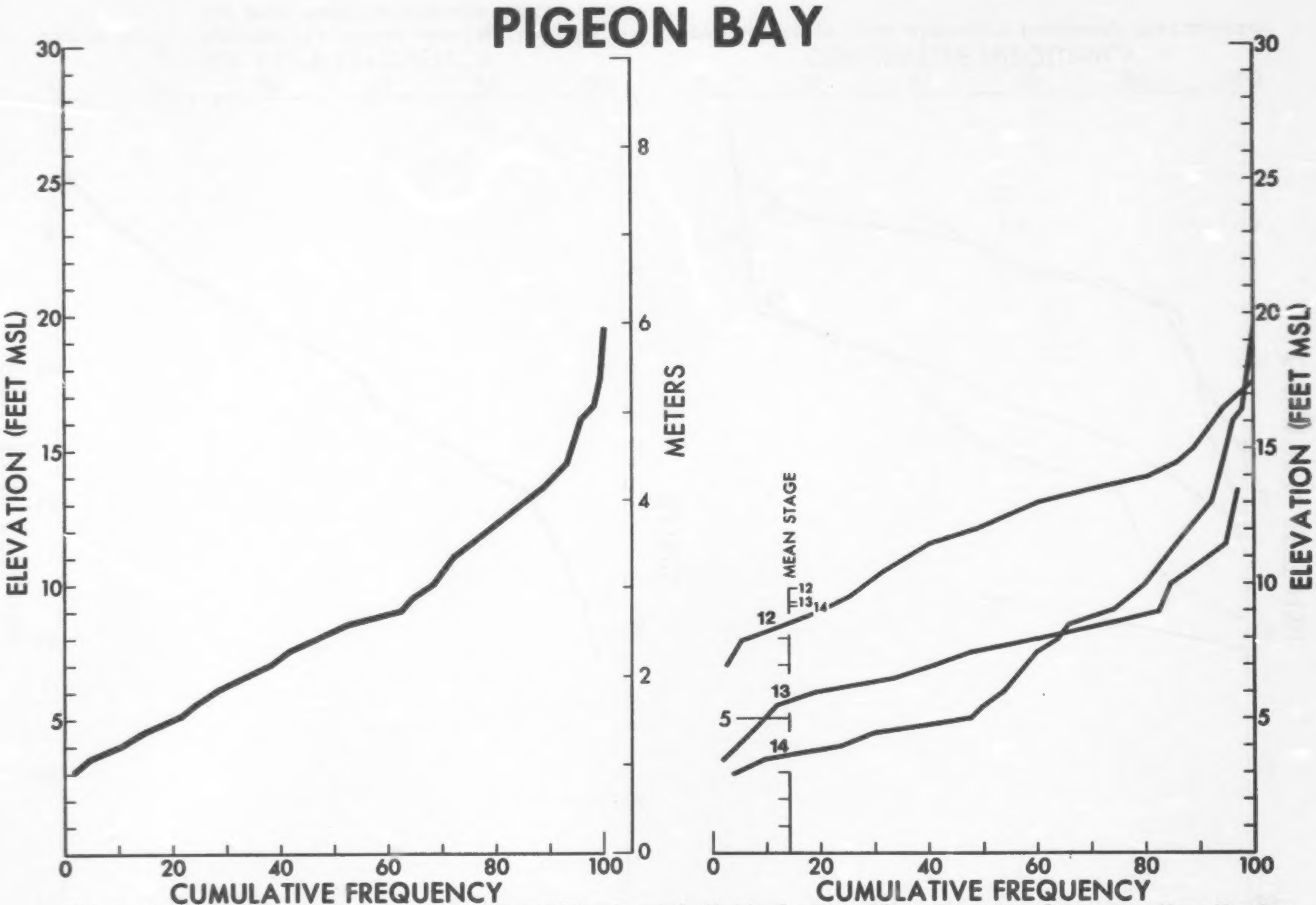


Figure 6-13. Hypsometric curves showing combined and individual range line elevation frequency distribution for Pigeon Bay Management Unit.

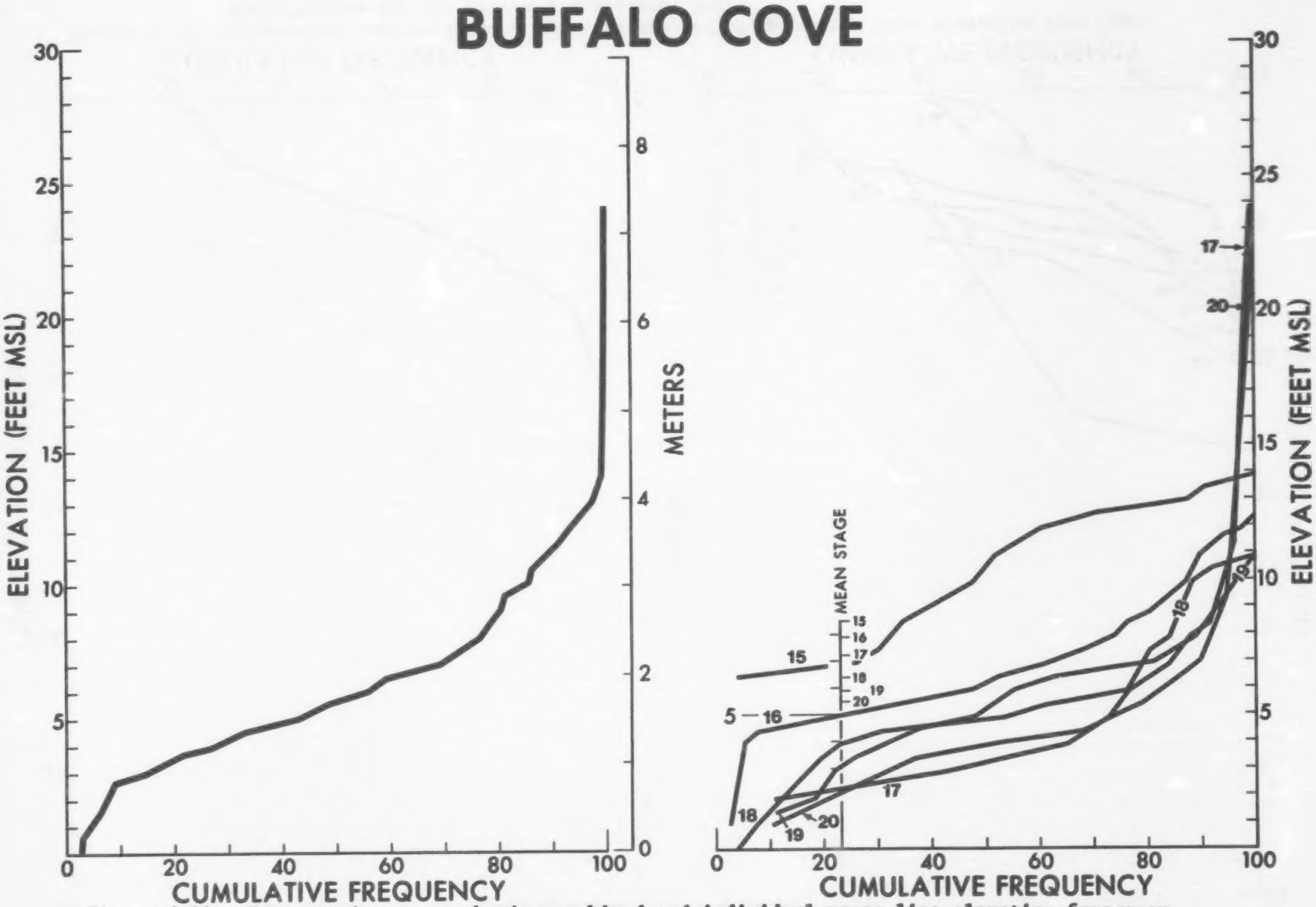


Figure 6-14. Hypsometric curves showing combined and individual range line elevation frequency distribution for Buffalo Cove Management Unit.

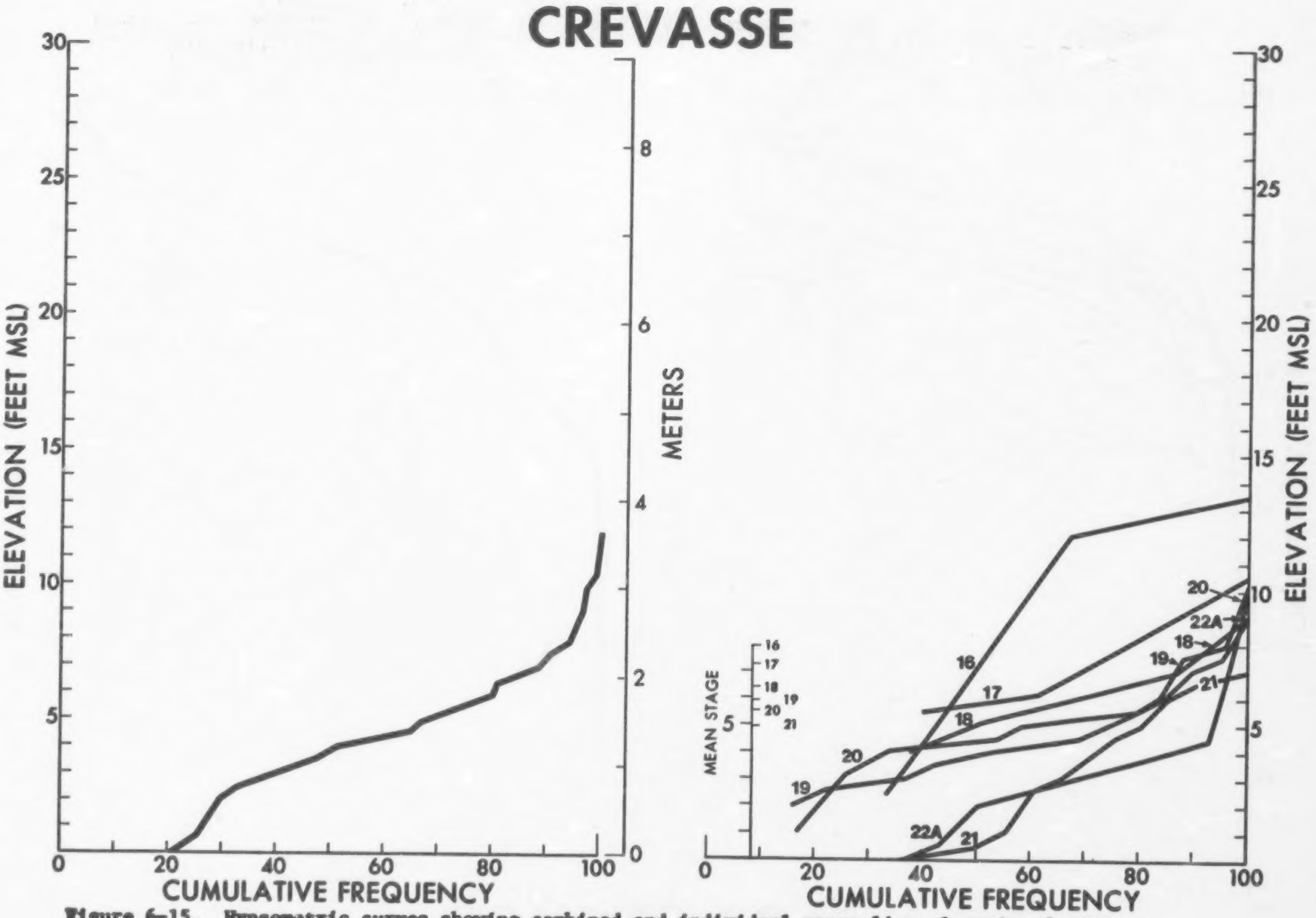


Figure 6-15. Hypsometric curves showing combined and individual range line elevation frequency distribution for the Crevasse Management Unit.

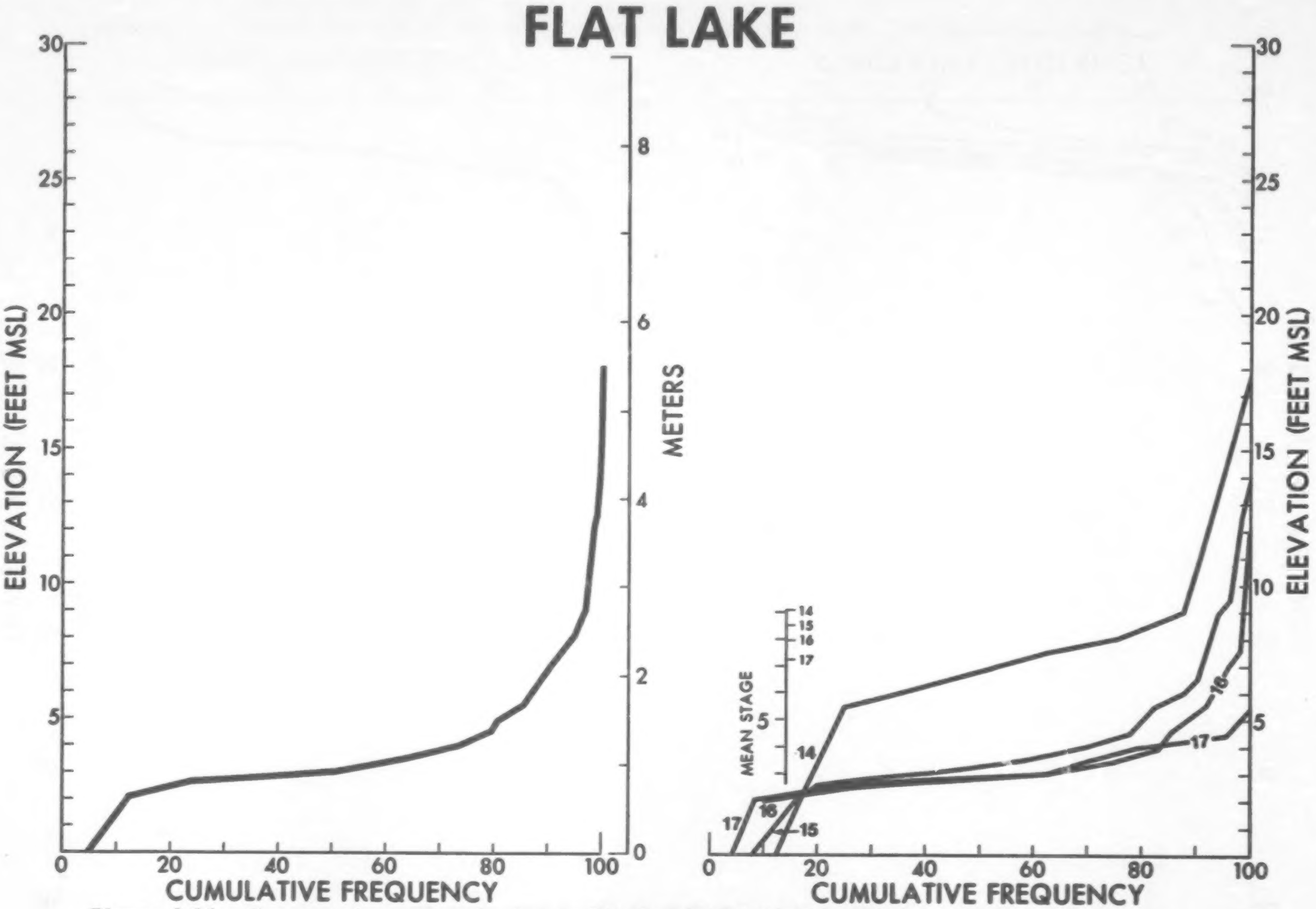


Figure 6-16. Hypsometric curves showing combined and individual range line elevation frequency distribution for Flat Lake Management Unit.

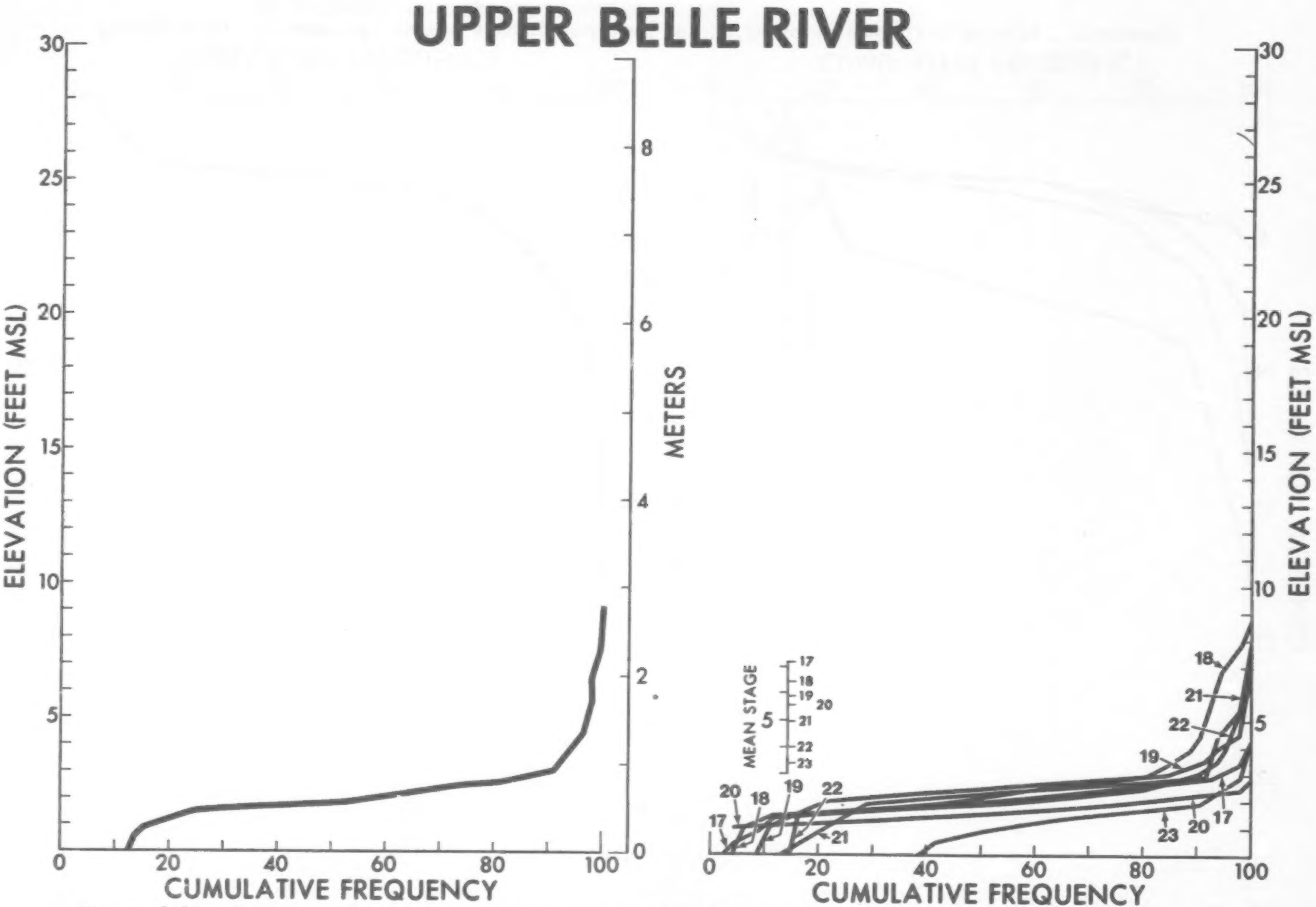


Figure 6-17: Hypsometric curves showing combined and individual range line elevation frequency distribution for Upper Belle River Management Unit.

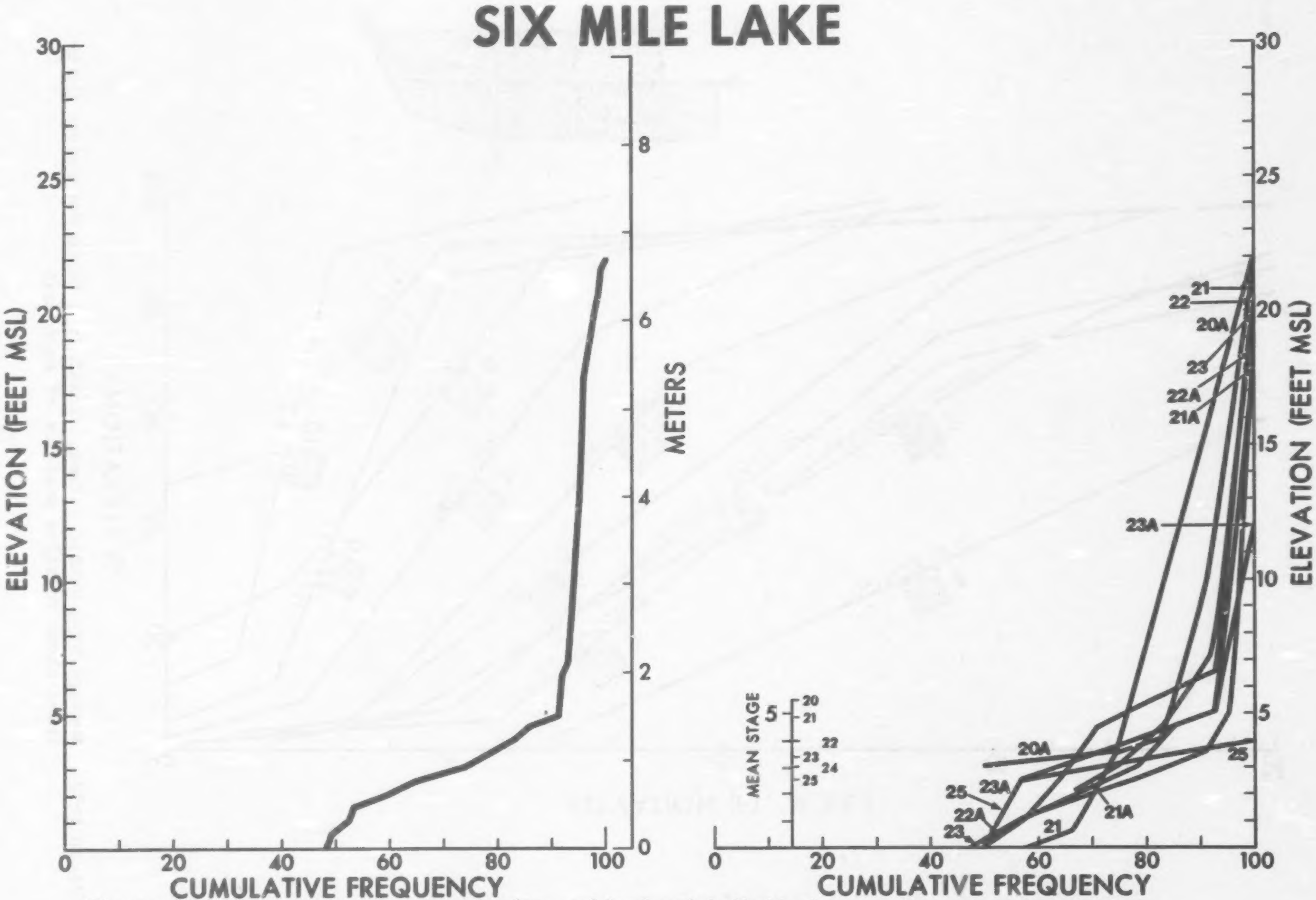


Figure 6-18. Hypsometric curves showing combined and individual range line elevation frequency distribution for Six Mile Lake Management Unit.

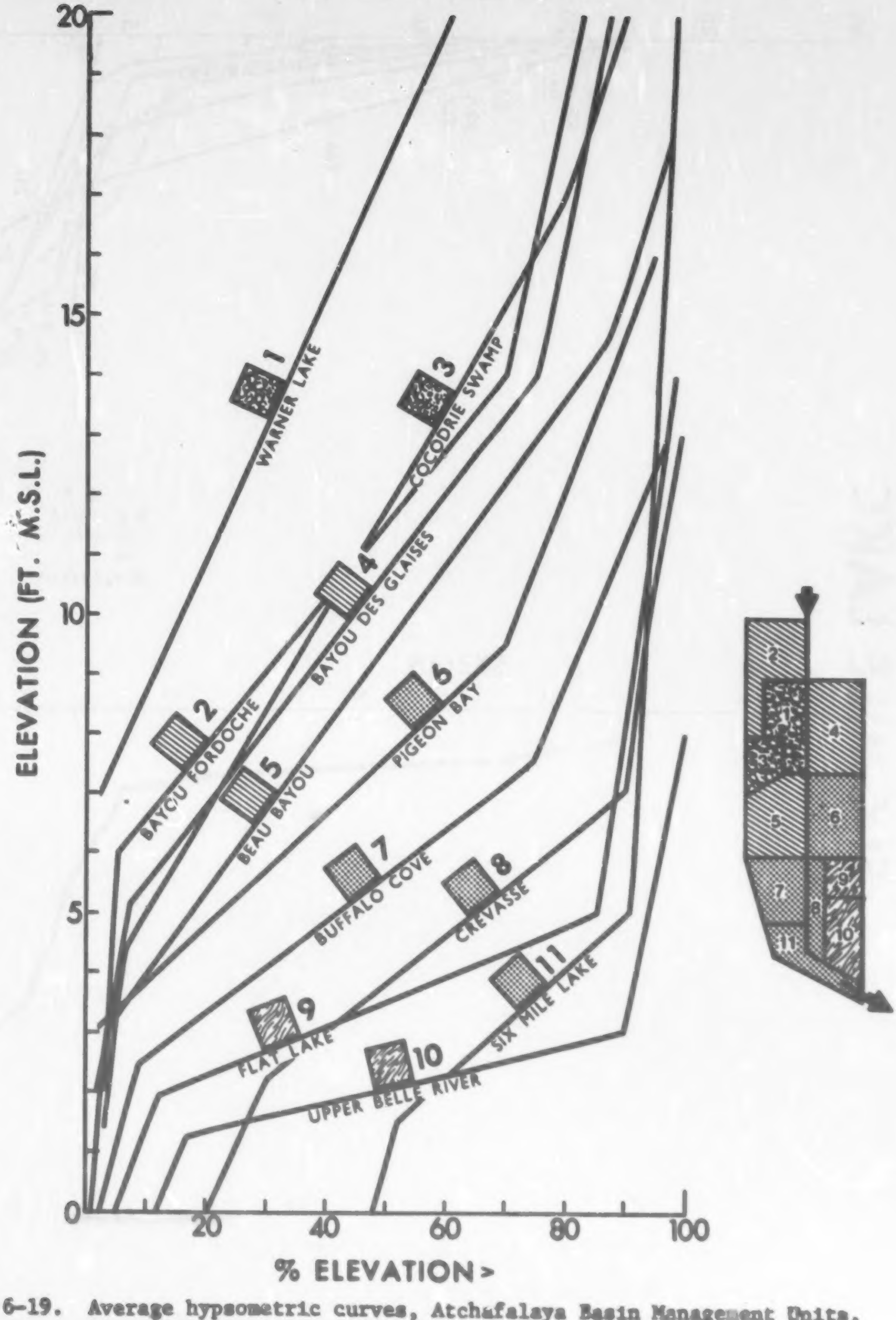


Figure 6-19. Average hypsometric curves, Atchafalaya Basin Management Units. Inset shows relative position of each unit.

The Buffalo Cove unit illustrates that we are indeed looking at temporal change as well as spatial variation. The hypsometric curves for this unit are shown in Fig. 6-20 for the three years, 1932, 1950, and 19(67/71). Over the 35-year period, the hypsometric characteristics of the Buffalo Cove Management Unit display the same change that is found from north to south in the overall central basin. Furthermore, through comparison, it can be stated that it took approximately 35 years for the Buffalo Cove Management Unit to move through a succession that brought it from a condition almost identical to that presently found in the Upper Belle River Management Unit to its present condition. Inversely, it may be reasoned that if present trends continue, in 35 years the northern part of the Upper Belle River unit will have attained characteristics similar to those of Buffalo Cove at present. It is this type of information that will contribute to improvement of the succession model in Fig. 6-1 as a tool for the development of management and land use guidelines.

Relationship of Habitat Types to Hypsometric Characteristics

Since the distribution of fauna and flora within the basin are controlled to a large extent by water levels, the hypsometric curves provide an ideal means of evaluating habitat. Given a certain water level, the hypsometric curve provides a simple determination of the percentage of the area submerged and the average depth of submergence. Consequently, this will also yield the area of dry land remaining. Such determinations may be made for different water levels related to annual stage variation.

The manner in which the combination of stage and hypsometric data can be applied in developing management guidelines becomes apparent when considering, for example, the habitat requirements for the red swamp crawfish (*Procambarus clarkii*). The crawfish is an economically important member of the basin fauna, with production to a large extent being dependent on water levels.

Crawfish breed in May and June when water levels in the swamp are still high (Fig. 6-21A). Soon after the breeding season, when water levels begin falling and the swamp is de-watered, females begin to burrow (Fig. 6-21B). Eggs may have been extruded prior to that in open water, but most of the spawning and hatching occurs in September and October. As water levels rise again, females and the young leave the burrow and forage in the shallow water on recently drowned vegetation (Fig. 6-21C). Related to the rise in water levels is an increase in the extent to which the crawfish become subject to predation. It forms the favorite food of largemouth and spotted bass. While during de-watering of the swamp, associated with high air and shallow water temperatures, these fish become concentrated in the deeper channels and lakes; they move back into the swamp after depths there increase sufficiently (Fig. 6-21D).

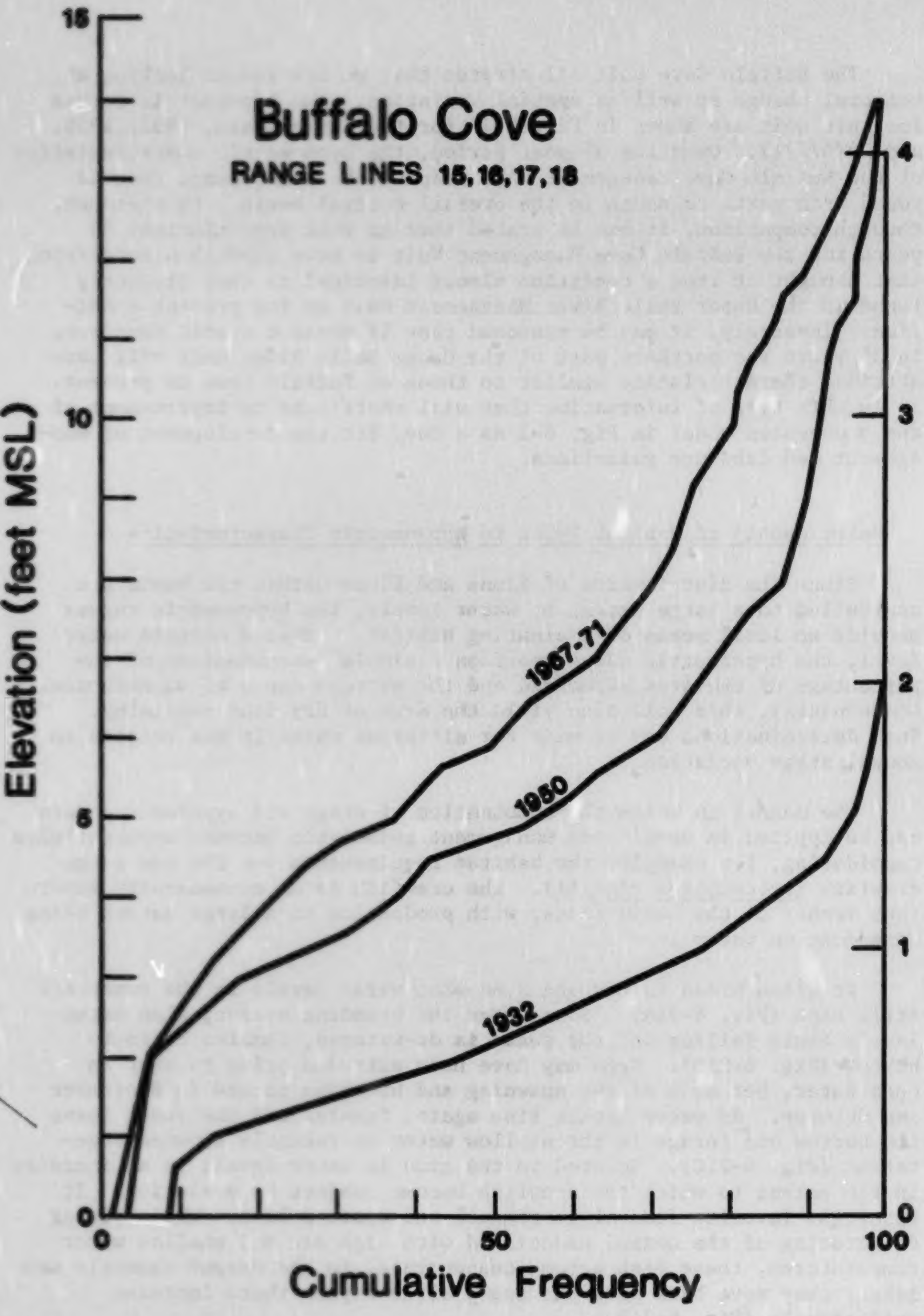


Figure 6-20. Hypsometric curves showing cumulative elevation frequencies for range lines 15, 16, 17, 18, in the Buffalo Cove Management Unit, 1932, 1950, 1967-71.

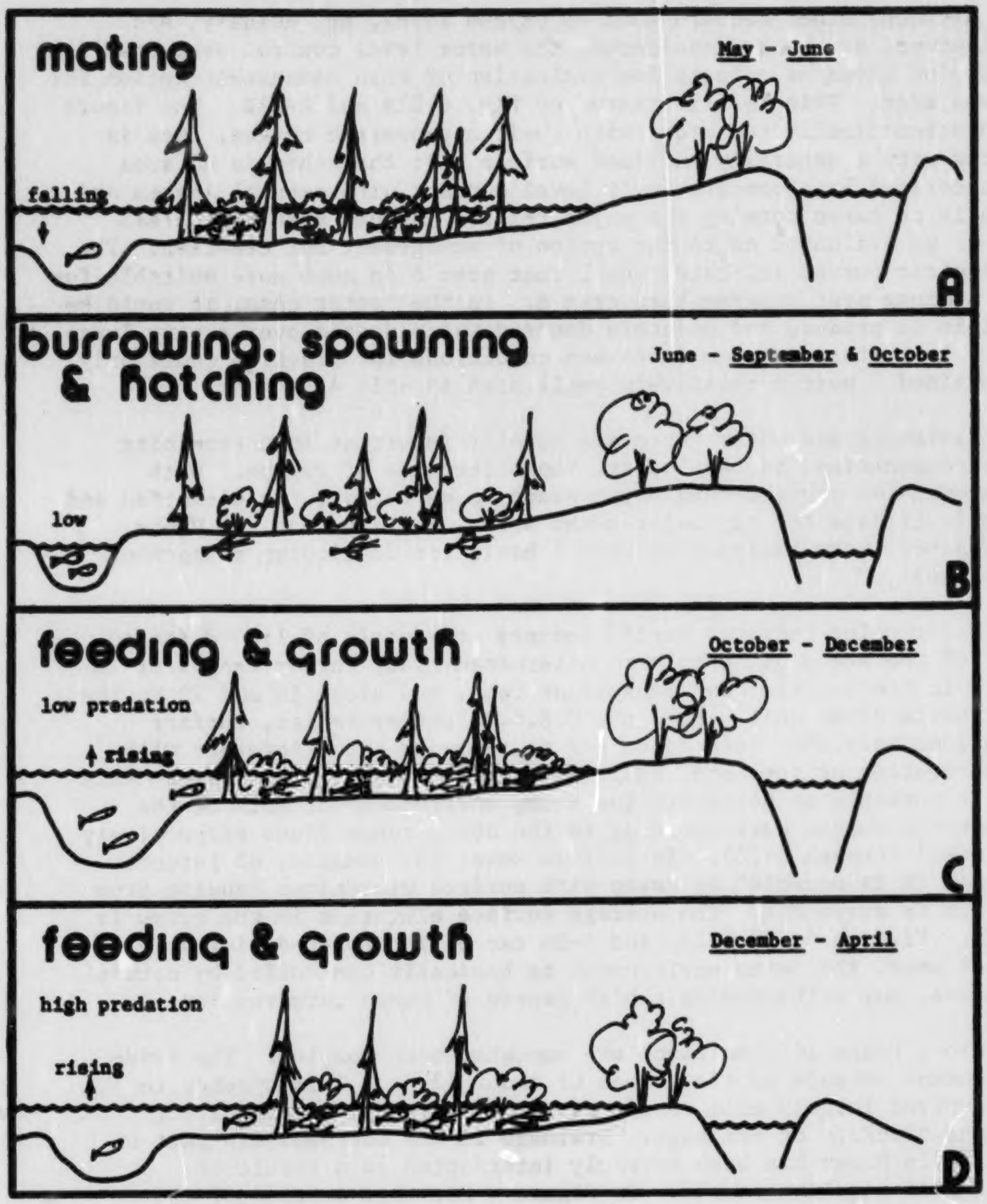

mating
May - June
falling
A
burrowing, spawning & hatching
June - September & October
low
B
feeding & growth
October - December
low predation
rising
C
feeding & growth
December - April
high predation
rising
D

Figure 6-21: Schematic sections showing seasonal basin activity for red swamp crawfish: A-breeding; B-burrowing, spawning, and hatching; C-feeding and growth with low predation; D-feeding and growth with high predation.

Although other factors such as oxygen level, pH, acidity, and temperature, are to be considered, the water level control over crawfish production gives us a basis for evaluation of this management option for a given area. This is illustrated by Fig. 6-22A and 6-22B. The figure shows schematically two areas with their hypsometric curves. One is an area with a generally inclined surface (A); the other is an area characterized by a comparatively level surface with natural levees and channels or lakes forming the major relief. Assume that both areas have to be evaluated as to the option of management for crawfish. The hypsometric curves indicate, then, that area B is much more suitable for such a management program than area A. In the latter case, it would be possible to produce and maintain desired water depths over a very large area. In contrast, assumed optimum conditions for crawfish could only be obtained over a relatively small area in unit A.

Elevation and water depth are equally important in determining plant communities, in particular, the occurrence of swamps. With management for cypress-tupelo gum swamp as an option, the elevation and water level data for two major swamp areas, Buffalo Cove and Upper Belle River, were analyzed to form a basis for developing management guidelines.

Using color-infrared aerial imagery at a scale of 1:9000 (NASA, 1972),[58] the areas of swamp were determined along survey ranges of 16 and 18 in the Buffalo Cove Management Unit, and along 18 and 22 in the Upper Belle River unit. From the U.S.C.E. survey ranges, surface elevations were then determined for these swamp areas together with the percentage of the total range line length occupied by swamp. This made it possible to delineate the swamp environment on each of the hypsometric curves corresponding to the above range lines respectively (Fig. 6-23 through 6-26). In Buffalo Cove, for example, 88 percent of range 18 is occupied by swamp with surface elevations ranging from 1 to 7.6 ft above MSL. The average surface elevation in the swamp is 2.2 ft. Figures 6-23, 6-25, and 6-26 can be interpreted similarly. In each case, the swamp environment is basically controlled by natural processes, not withstanding a high degree of human intervention.

Along range 16 conditions are somewhat more complex. The swamp environment extends to elevations of about 12 ft. This appears to have evolved largely as a result of purged water levels resulting from the blockage of drainage. Drainage in the northeastern part of Upper Belle River has been severely interrupted as a result of dredging of pipeline canals. On Figure 6-23, this section of the swamp is identified as spoil elevated.

Ideally, swamp surface elevations should be related to water levels in the swamp. Unfortunately, such data is non-existent and

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[58] NASA (MTF), Land Remote Sensing Program, Atchafalaya River Basin Study, Part II (Houston, Texas: Manned Spacecraft Center, 1972).

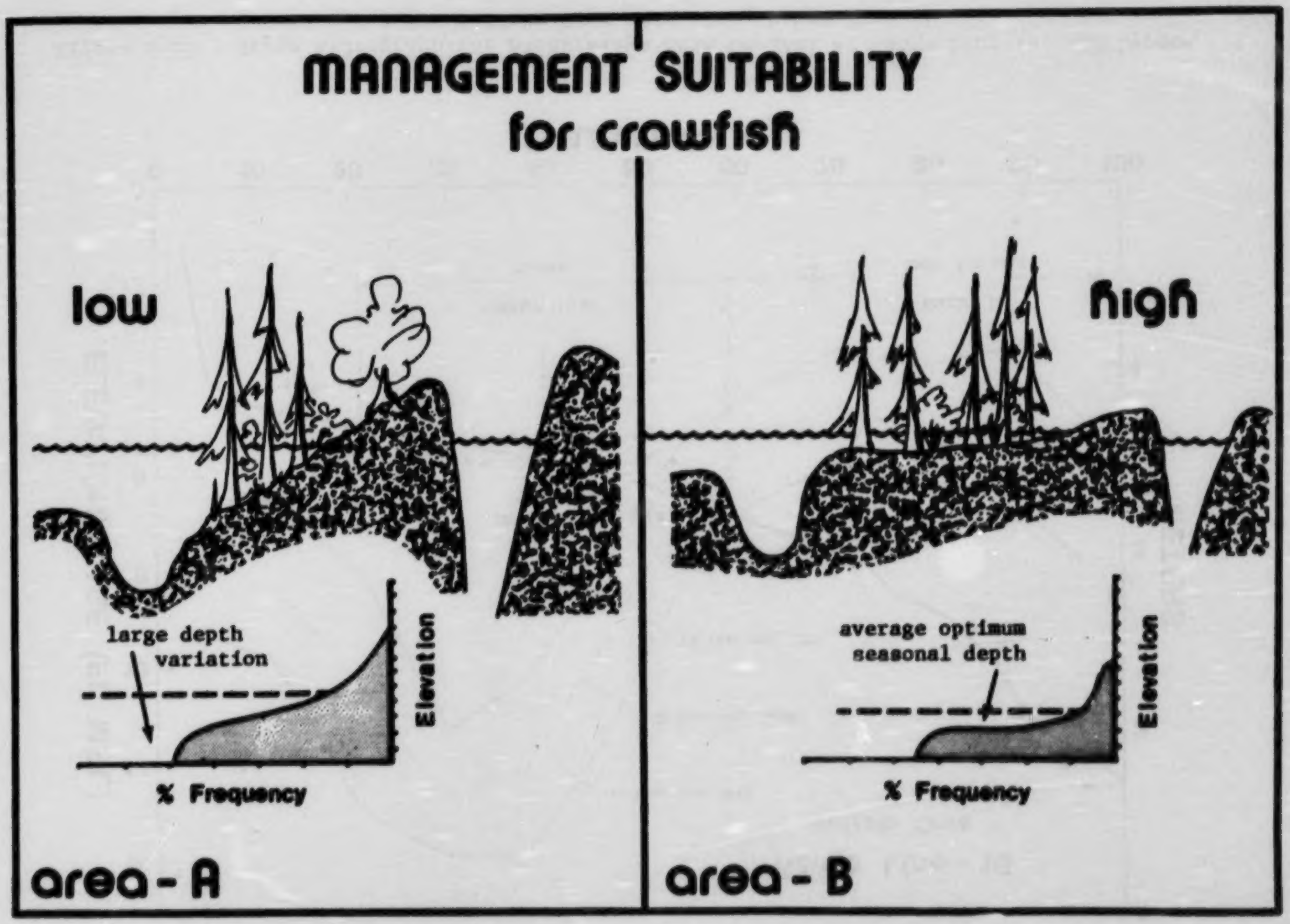

MANAGEMENT SUITABILITY
for crawfish
low
high
large depth variation
Elevation
% Frequency
area - A
average optimum seasonal depth
Elevation
% Frequency
area - B

Figure 6-22· Schematic sections showing area-A, inclined surface condition with low crawfish management suitability; area-B, flat surface condition with high crawfish management suitability.

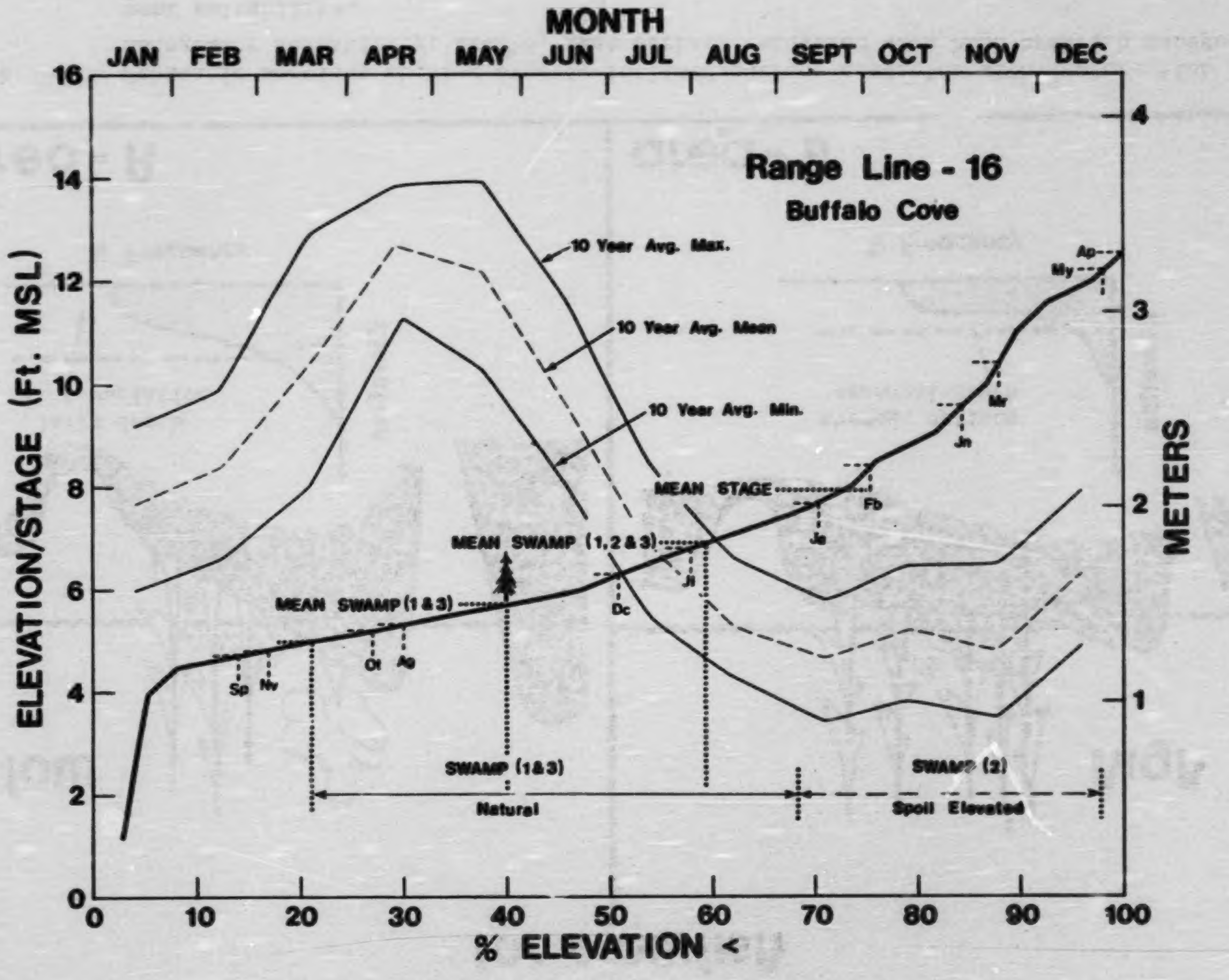


Figure 6-23. Stage hydrograph for Atchafalaya Main Channel at Range line 16, and hypsometric curve for Buffalo Cove unit along Range line 16.

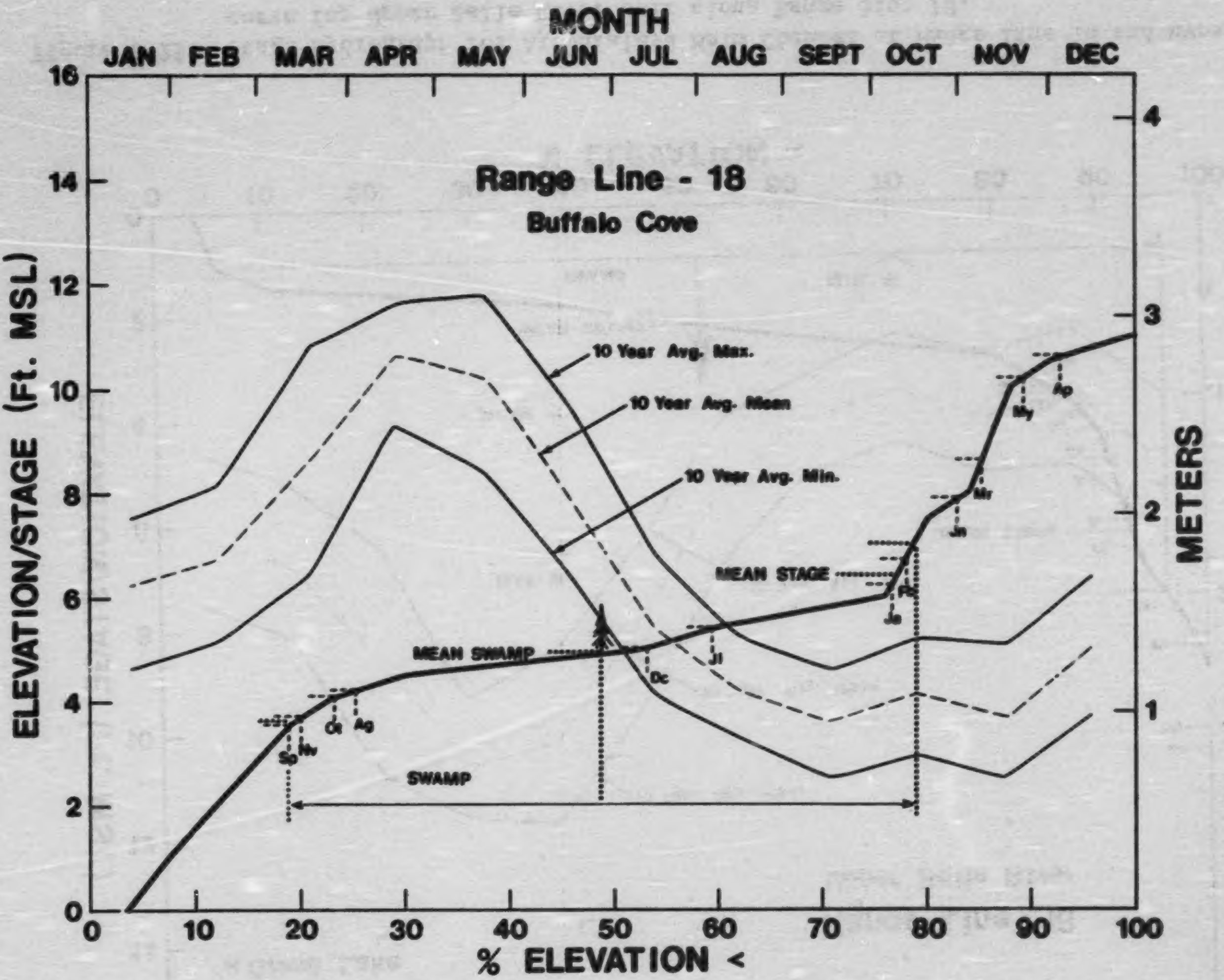


Figure 6-24. Stage hydrograph for Atchafalaya Main Channel at Range line 18, and hypsometric curve for Buffalo Cove unit along Range line 18.

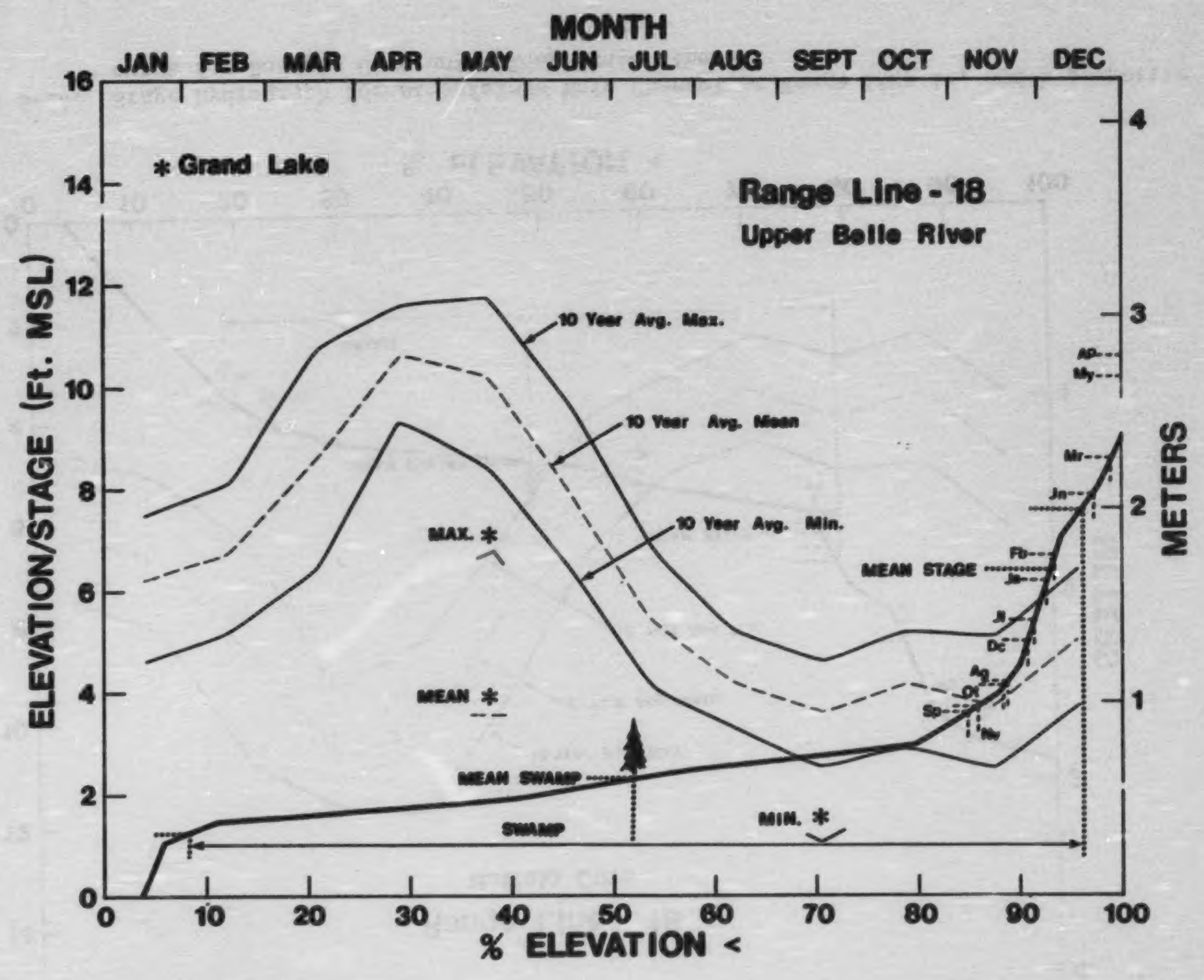


Figure 6-25. Stage hydrograph for Atchafalaya Main Channel at Range line 18 and hypsometric curve for Upper Belle River unit along Range line 18.

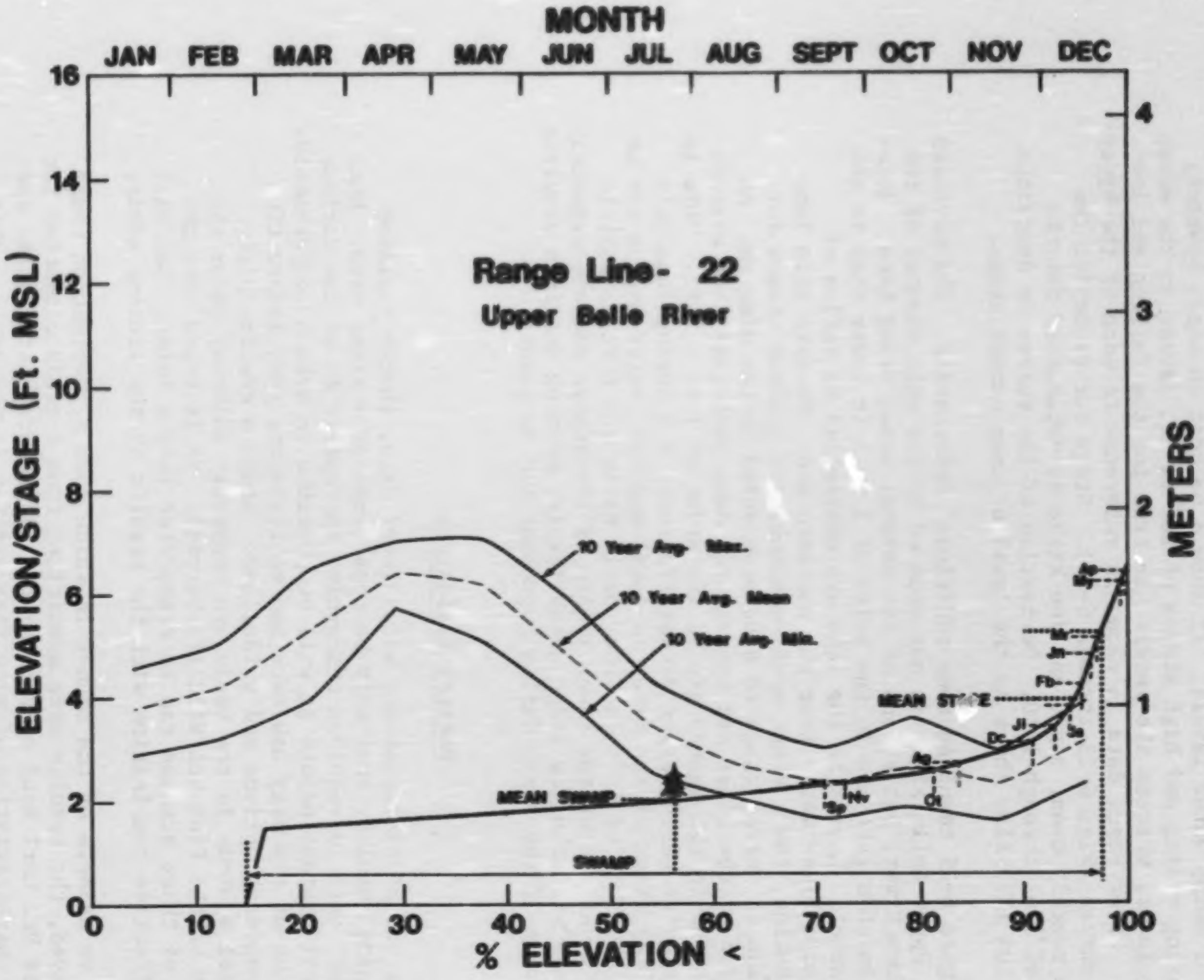


Figure 6-26. Stage hydrograph for Atchafalaya Main Channel at Range line 22, and hypsometric curve for Upper Belle River unit along Range line 22.

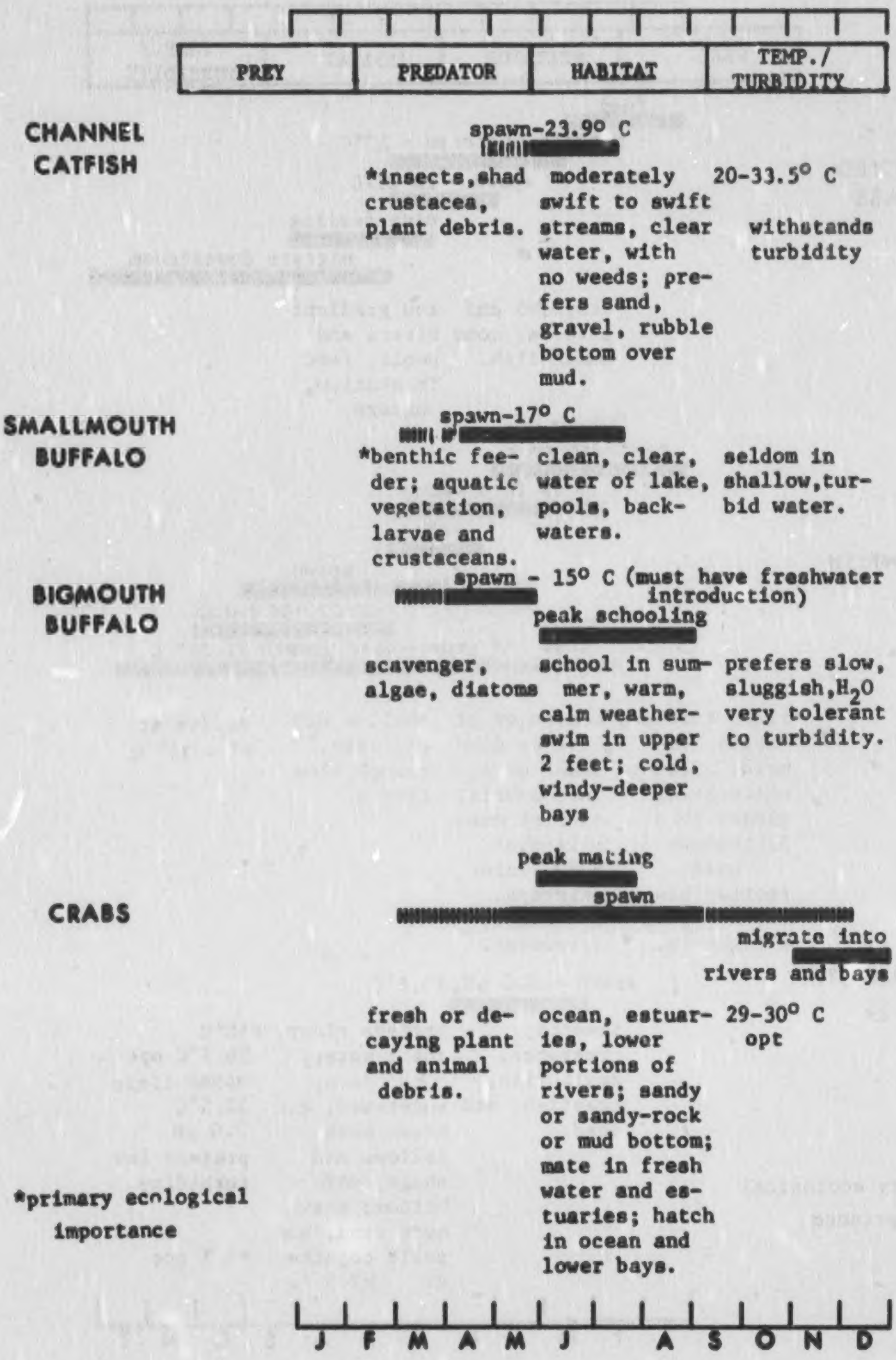
Atchafalaya River levels had to be used instead as a first approximation of swamp water levels. It should be kept in mind, however, that during rising and high stages of the river, levels in the swamp will be lower, whereas the reverse is true for the falling and low stages. River stage data is shown in reference to each of the hypsometric curves (Fig. 6-23 through 6-26). Stage curves depict the average monthly mean, high, and low stage as determined for the period of 1961 through 1970. Derivation of the curves is described in Section IX. Also shown is the level of mean annual stage.

Figure 6-25 requires some additional information. The northern half of Upper Belle River is not bounded by the main channel of the Atchafalaya River, but by one of its several arms, Grand Lake. Water levels in this lake are in the order of 2 to 3 ft lower than in the main channel. Levels in the lake are controlled by inflow of Atchafalaya River water from the southern end. To take this into consideration, the average mean, maximum, and minimum stages for Grand Lake at survey range 18 have been added to the diagram. An evaluation of the stage and hypsometric data indicates that average water depths in the swamps are in the order of 1 to 1.5 ft. This is also the water depth during January/February and during June/July. During high stage of the river in April and May, water depths are in the neighborhood of 4 ft in Upper Belle River and 6 ft in Buffalo Cove. Elevations at the lower limits of the swamps are approximately coincident with the low stage water levels, meaning nearly a complete de-watering of the swamp during September and November.

Habitat Evaluation

The use of elevation and water level data, though yielding encouraging results, must only be considered as a first step. Much additional data is required concerning the operation of the various biological systems before it will be possible to make a comprehensive evaluation of the many habitats and to translate that information into management options and guidelines. Studies dealing with biological systems in the basin are presently underway under the auspices of the Fish and Wildlife Service. It is hoped that the results of these studies can be translated into a format that will allow effective combination with the results of the present study.

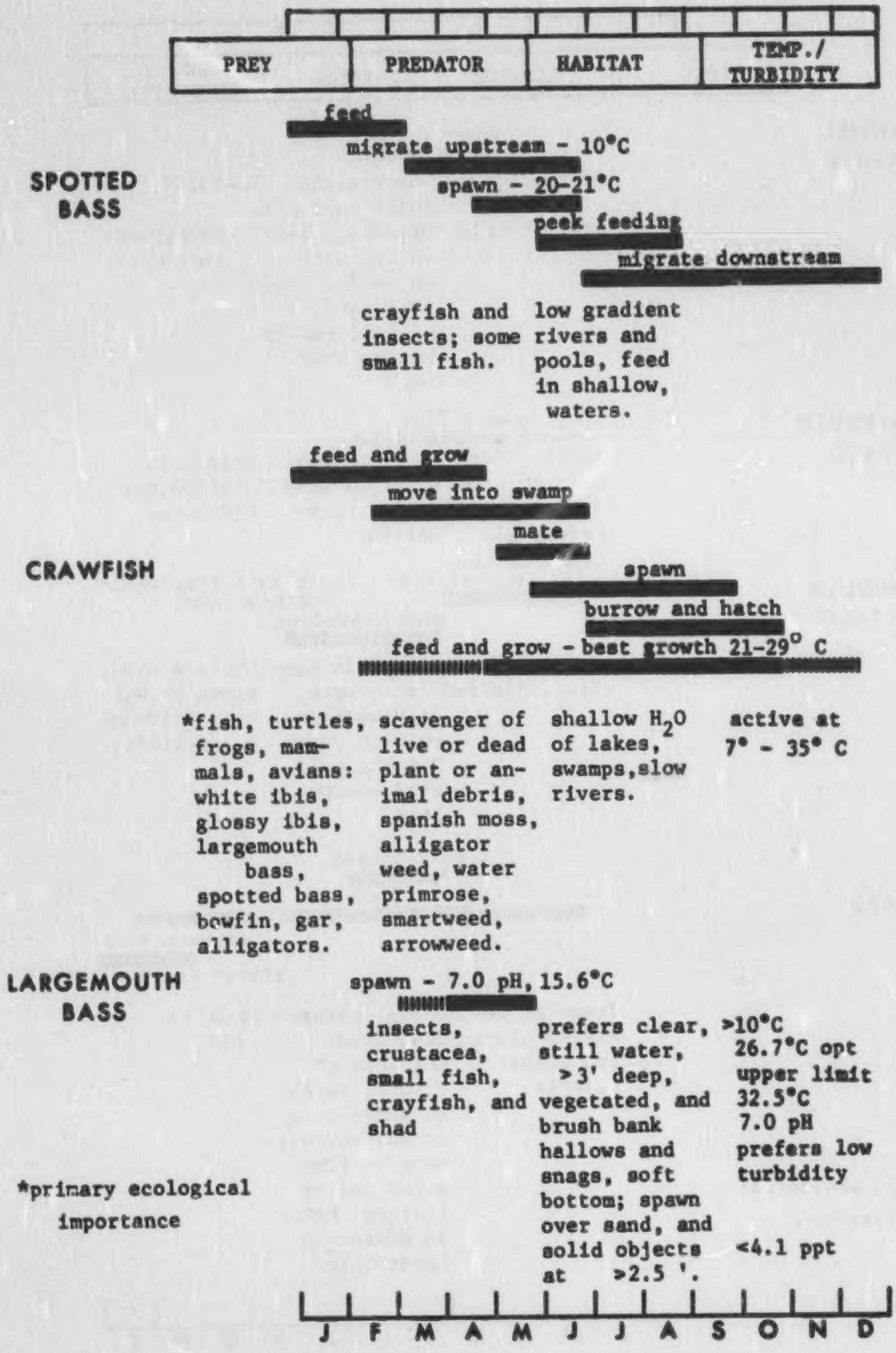
As an example of the manner in which such a combination could be achieved, the results were summarized from a study conducted for E.P.A. by Dr. Carl Bond concerning the importance, life cycle, and habitat characteristics of many fish species in the basin. This summary is presented in Tables 6-1 through 6-5. Life cycle information as given by the horizontal bars is placed on a time scale corresponding to that of the stage hydrograph curves presented in Appendix A, Hydrographs. The occurrence of a certain phase in the life cycle can thus be directly compared to conditions of river stage and temperature. Combining this information with habitat preference and hypsometric data



		PREY	PREDATOR	HABITAT	TEMP./ TURBIDITY
CHANNEL CATFISH	spawn-23.9° C		*insects,shad crustacea, plant debris.	moderately swift to swift streams, clear water, with no weeds; prefers sand, gravel, rubble bottom over mud.	20-33.5° C withstands turbidity
SMALLMOUTH BUFFALO	spawn-17° C		*benthic feeder; aquatic vegetation, larvae and crustaceans.	clean, clear, water of lake, pools, backwaters.	seldom in shallow,turbid water.
BIGMOUTH BUFFALO	spawn - 15° C (must have freshwater introduction) peak schooling		scavenger, algae, diatoms	school in summer, warm, calm weather-swim in upper 2 feet; cold, windy-deeper bays	prefers slow, sluggish,H_2O very tolerant to turbidity.
CRABS	peak mating spawn migrate into rivers and bays		fresh or decaying plant and animal debris.	ocean, estuaries, lower portions of rivers; sandy or sandy-rock or mud bottom; mate in fresh water and estuaries; hatch in ocean and lower bays.	29-30° C opt

*primary ecological importance

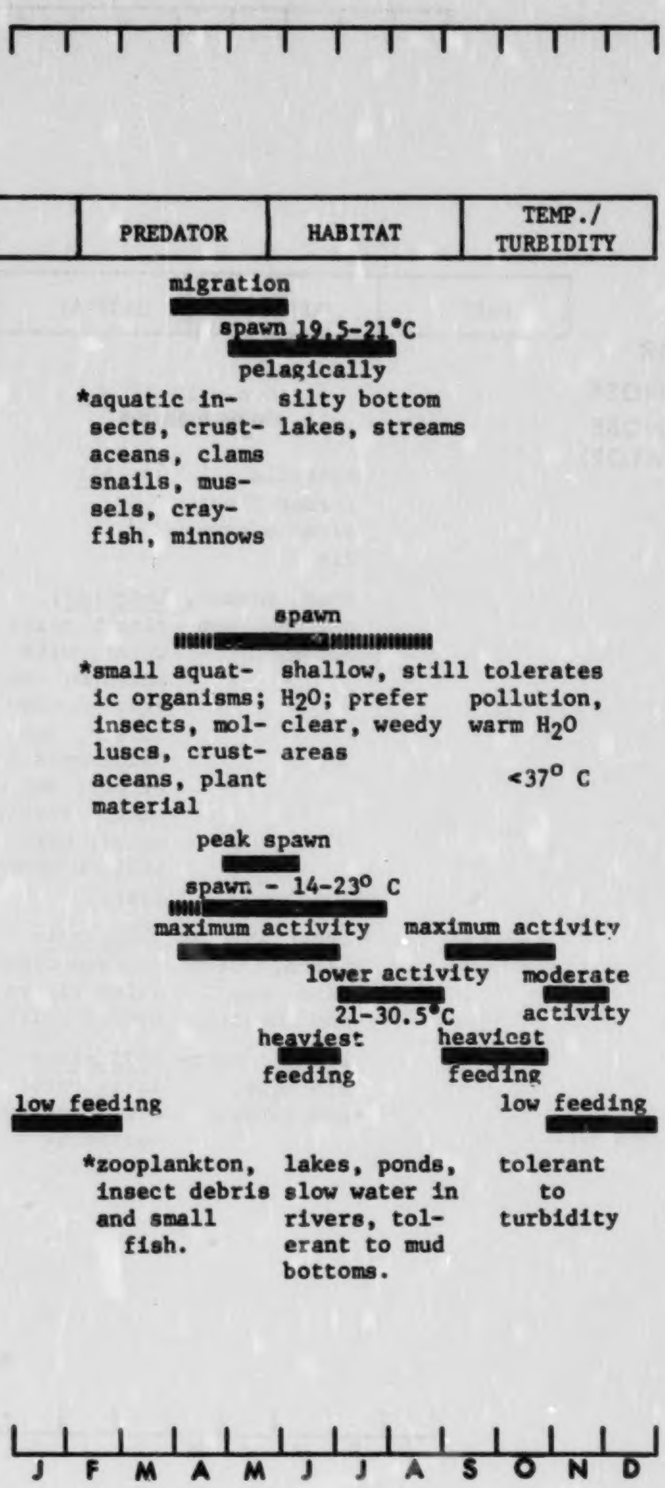
Table 6-1. Importance, life cycle, and habitat characteristics of indicator fish species in the Atchafalaya Basin, Louisiana.



	PREY	PREDATOR	HABITAT	TEMP./ TURBIDITY
SPOTTED BASS		crayfish and insects; some small fish.	low gradient rivers and pools, feed in shallow, waters.	
CRAWFISH	*fish, turtles, frogs, mammals, avians: white ibis, glossy ibis, largemouth bass, spotted bass, bowfin, gar, alligators.	scavenger of live or dead plant or animal debris, spanish moss, alligator weed, water primrose, smartweed, arrowweed.	shallow H_2O of lakes, swamps, slow rivers.	active at 7° - 35° C
LARGEMOUTH BASS		insects, crustacea, small fish, crayfish, and shad	prefers clear, still water, >3' deep, vegetated, and brush bank hallows and snags, soft bottom; spawn over sand, and solid objects at >2.5 '.	>10°C 26.7°C opt upper limit 32.5°C 7.0 pH prefers low turbidity <4.1 ppt

*primary ecological importance

Table 6-2: Importance, life cycle, and habitat characteristics of indicator fish species in the Atchafalaya Basin, Louisiana.



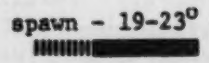
	PREY	PREDATOR	HABITAT	TEMP./ TURBIDITY
FRESHWATER DRUM		*aquatic insects, crustaceans, clams snails, mussels, crayfish, minnows	silty bottom lakes, streams	
BULLHEAD (YELLOW, BLACK, BROWN)		*small aquatic organisms; insects, molluscs, crustaceans, plant material	shallow, still H_2O; prefer clear, weedy areas	tolerates pollution, warm H_2O <37° C
WHITE CRAPPIE		*zooplankton, insect debris and small fish.	lakes, ponds, slow water in rivers, tolerant to mud bottoms.	tolerant to turbidity

*primary ecological importance

Table 6-3. Importance, life cycle, and habitat characteristics of indicator fish species in the Atchafalaya Basin, Louisiana.

GAR
(LONGNOSE
SHORTNOSE
ALLIGATOR)

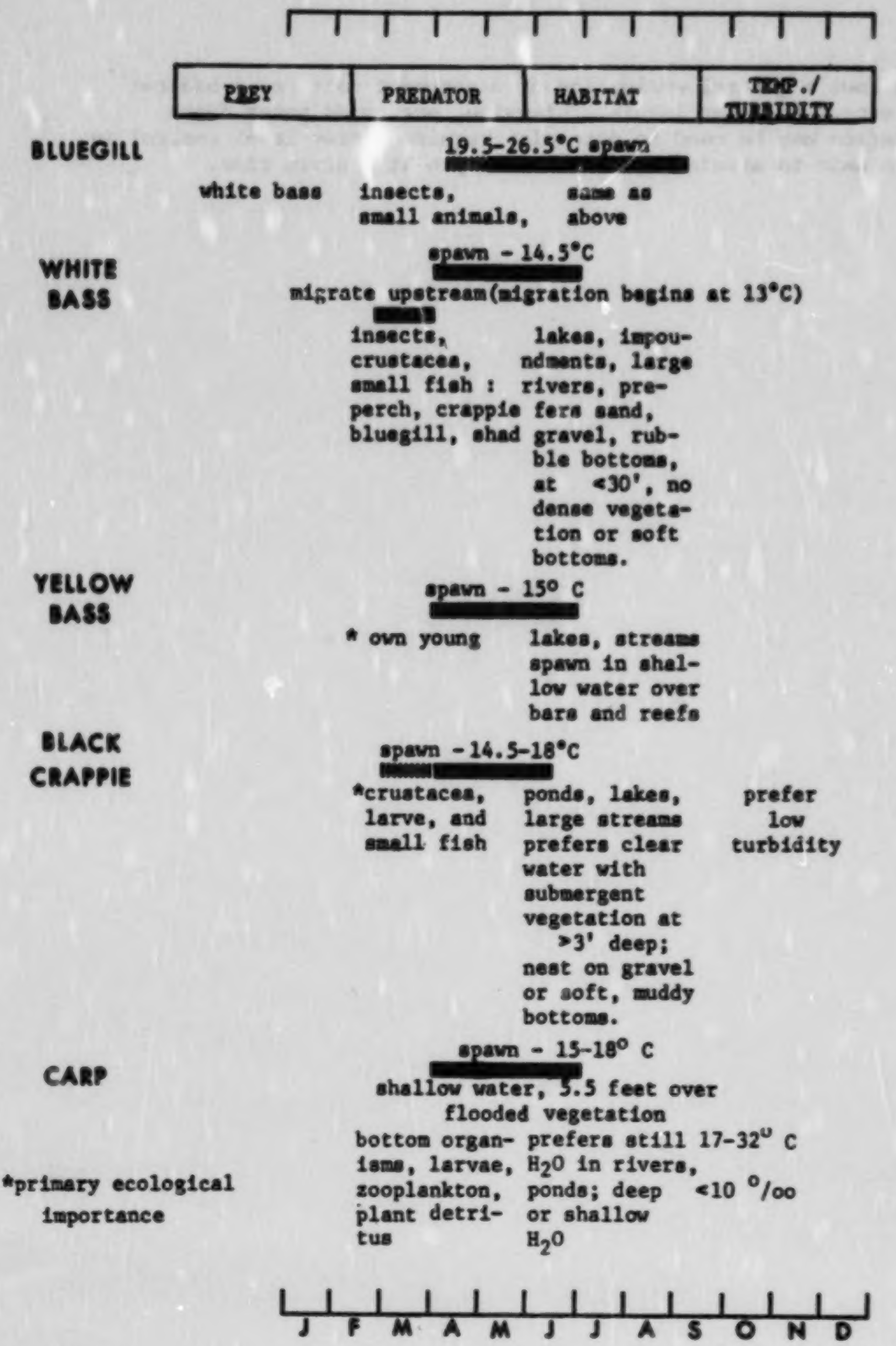
spawn - 19-23° C



PREY	PREDATOR	HABITAT	TEMP./ TURBIDITY
	controls forage fish; birds & game fish.	All	can tolerate high temperatures
	shad, minnow, catfish, menhaden.	Longnose: clear, quiet water, with abundant vegetation, slow rivers, impoundments & oxbows; may enter brackish water, over shallow mudflats;	3-10 ppt salinity
	crayfish, perch, sunfish, carp, and insects.	Shortnose: prefers open silty rivers, avoids quiet.	tolerates turbidity
	fish, invertebrates, and birds;	Alligator: large water areas, often marine or brackish;	<25 ppt salinity

J F M A M J J A S O N D

Table 6-4. Importance, life cycle, and habitat characteristics of indicator fish species in the Atchafalaya Basin, Louisiana.



	Life cycle	PREY	PREDATOR	HABITAT	TEMP./ TURBIDITY
BLUEGILL	19.5-26.5°C spawn	white bass	insects, small animals,	same as above	
WHITE BASS	spawn - 14.5°C migrate upstream(migration begins at 13°C)		insects, crustacea, small fish : perch, crappie bluegill, shad	lakes, impoundments, large rivers, prefers sand, gravel, rubble bottoms, at <30', no dense vegetation or soft bottoms.	
YELLOW BASS	spawn - 15° C		* own young	lakes, streams spawn in shallow water over bars and reefs	
BLACK CRAPPIE	spawn -14.5-18°C		*crustacea, larve, and small fish	ponds, lakes, large streams prefers clear water with submergent vegetation at >3' deep; nest on gravel or soft, muddy bottoms.	prefer low turbidity
CARP	spawn - 15-18° C shallow water, 5.5 feet over flooded vegetation		bottom organisms, larvae, zooplankton, plant detritus	prefers still H_2O in rivers, ponds; deep or shallow H_2O	17-32° C <10 °/oo

*primary ecological importance

Table 6-5. Importance, life cycle, and habitat characteristics of indicator fish species in the Atchafalaya Basin, Louisiana.

then allows a general evaluation of management units as a habitat with respect to water levels. Likewise, preferred water depth information may be used to determine required water level control in a given unit to attain the preferred depth at a given time.

SECTION VII

RIVER INPUT

Discharge

The Atchafalaya River is a distributary of the Red and Mississippi Rivers, carrying all of the flow of the former and a substantial portion of the latter. That portion of flow which enters the Atchafalaya River from the Mississippi has been maintained at a constant level of approximately 30 percent since the completion of the Old River control structure in 1963. Prior to 1963, the Atchafalaya River had been receiving an increasing portion of Mississippi River flow, and total diversion of the Mississippi down the Atchafalaya River was seen as an imminent probability as early as the late 1800's (Fisk, 1952).[59] The Old River control structure has eliminated the possibility of complete diversion and restricts the flow entering the Atchafalaya River to 30 percent.

Discharge of the Atchafalaya River shows considerable variation, both seasonally and annually. The average annual discharge for the Atchafalaya River at Simmesport, Louisiana since 1963 is 169,500 cfs, with an average maximum discharge of 781,000 cfs on May 12, 1973. Not only does the maximum flow greatly exceed the average flow, but the average minimum flow for the same period is very much lower than the average flow. The average minimum flow is 62,000 cfs, with an absolute minimum of 10,500 cfs on January 24, 1964.

The average monthly discharge hydrography at Simmesport for the period of 1963-1971 indicates the seasonal distribution of the variable discharge of the Atchafalaya River (Figure 7-1). Over the 9-year period there is a distinct high flow period and a distinct low flow period, with flows being higher than average (169,500 cfs) from January to June and lower than average from July to December. Although high or low discharges can occur at any time of the year in response to corresponding discharges of the Mississippi System, flow generally begins to increase in December or January, and crest in the period between April and early June. The flows then drop off sharply to their normal seasonal lows in late summer and early fall (August, September, October), completing the typical annual cycle of high and low flow in the Atchafalaya Basin.

Distribution of Flow

The Atchafalaya River became a distributary of the Mississippi River approximately 1500 A.D. (Fisk, 1952),[60] but did not begin to draw

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[59] H. N. Fisk, 1952, *op. cit.*

[60] *Ibid.*

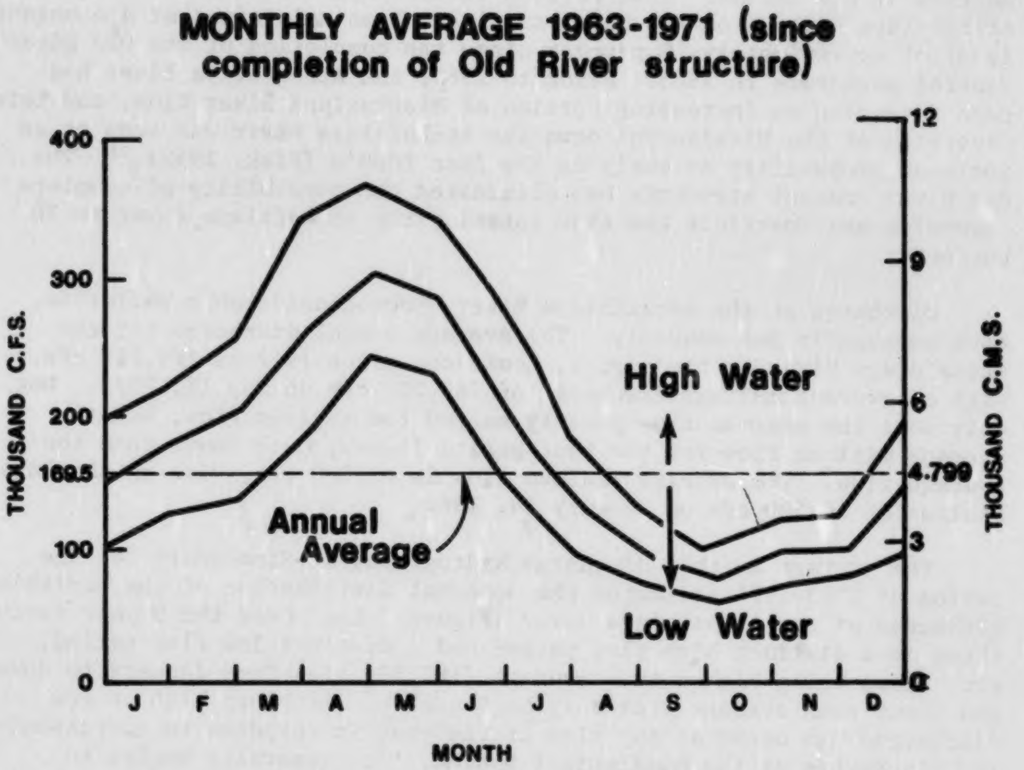

Figure 7-1. Discharge hydrograph of the Atchafalaya River at Simmesport, Louisiana, 1963-1971.

a significant portion of the flow until after some navigation improvements were completed in the middle 1800's. As discharge down the Atchafalaya River increased, flooding in the Atchafalaya Basin became a growing problem. Levee construction along the river began in 1881 and extended progressively downstream to its present limit (mile 52--see Appendix C, Plate 2) in 1940 in an attempt to confine the flow to the main channel.

The Flood Control Acts of 1928 and 1936, following the aftermath of the disasterous 1927 flood, designated the Atchafalaya Basin as a floodway to be used to alleviate high water on the Mississippi. With completion of the east and west side protection levees, the Atchafalaya Floodway became an entirely enclosed basin of 820,000 sq. miles with a primary function of siphoning off excess flood water from the Mississippi River. In 1942 an extra outlet was constructed to help facilitate more rapid movement of flood water through the Floodway. Improvements and minor additions to the floodway system have continued to the present, but it essentially exists as designated by the Flood Control Acts (see Appendix C, Plate 2).

Water from the Mississippi System enters the Atchafalaya Floodway via the main channel of the Atchafalaya River at Simmesport. The water is confined within artificial levees for the first 52 miles. From this point downstream to Morgan City, the flow is no longer confined by the levees along the river, but is allowed to spread between the east side and west side protection levees, an area approximately 15 miles wide.

For the past 50 years, the Atchafalaya River has been attempting to develop and increase the efficiency of its main channel through this unconfined section. Evidence of this increased efficiency can be seen in Figure 7-2. The diagram indicates that the River has flattened its profile since 1943 and thus is carrying approximately the same sediment load at a lower grade. According to Hubbard (1968),[61] this increase in efficiency is due primarily to increasing the cross-sectional area of the channel. The increase in cross-sectional area is due to both natural processes and dredging by the U. S. Corps of Engineers. According to surveys by the Corps since 1916, the channel has been developing through this unconfined section at a rate of one-half mile per year. Channel development is now complete to Myette Point (see Figure 7-3). Below Myette Point, the flow diverges into numerous major and minor channels until it exits the floodway via either the Wax Lake Outlet (30 percent of the flow) or the Lower Atchafalaya River (70 percent of the flow). The 15 percent of the flow not carried in the main channel upstream from Myette Point is distributed across the basin by various cross basin channels and canals, tributaries and distributaries, as well as overland flow through the backswamps.

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[61] Allen S. Hubbard, Study of Sedimentation in Grand and Six Mile Lakes, Atchafalaya Basin, La. (Thesis, Tulane University, 1968), 35 pp.

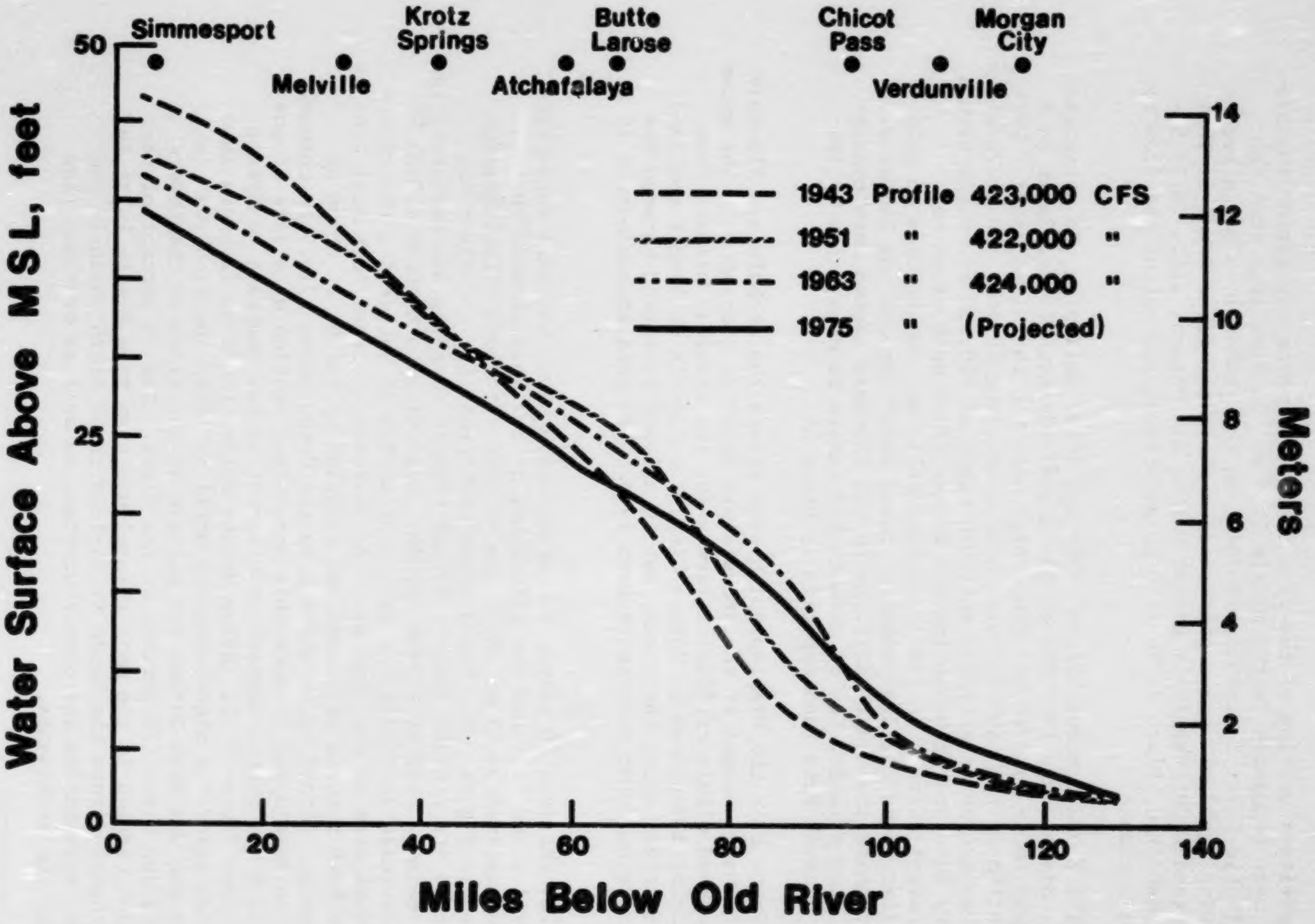

Figure 7-2. Atchafalaya River profiles, 1943-1975 (after Hubbard, 1968[62]).

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[62] Ibid.

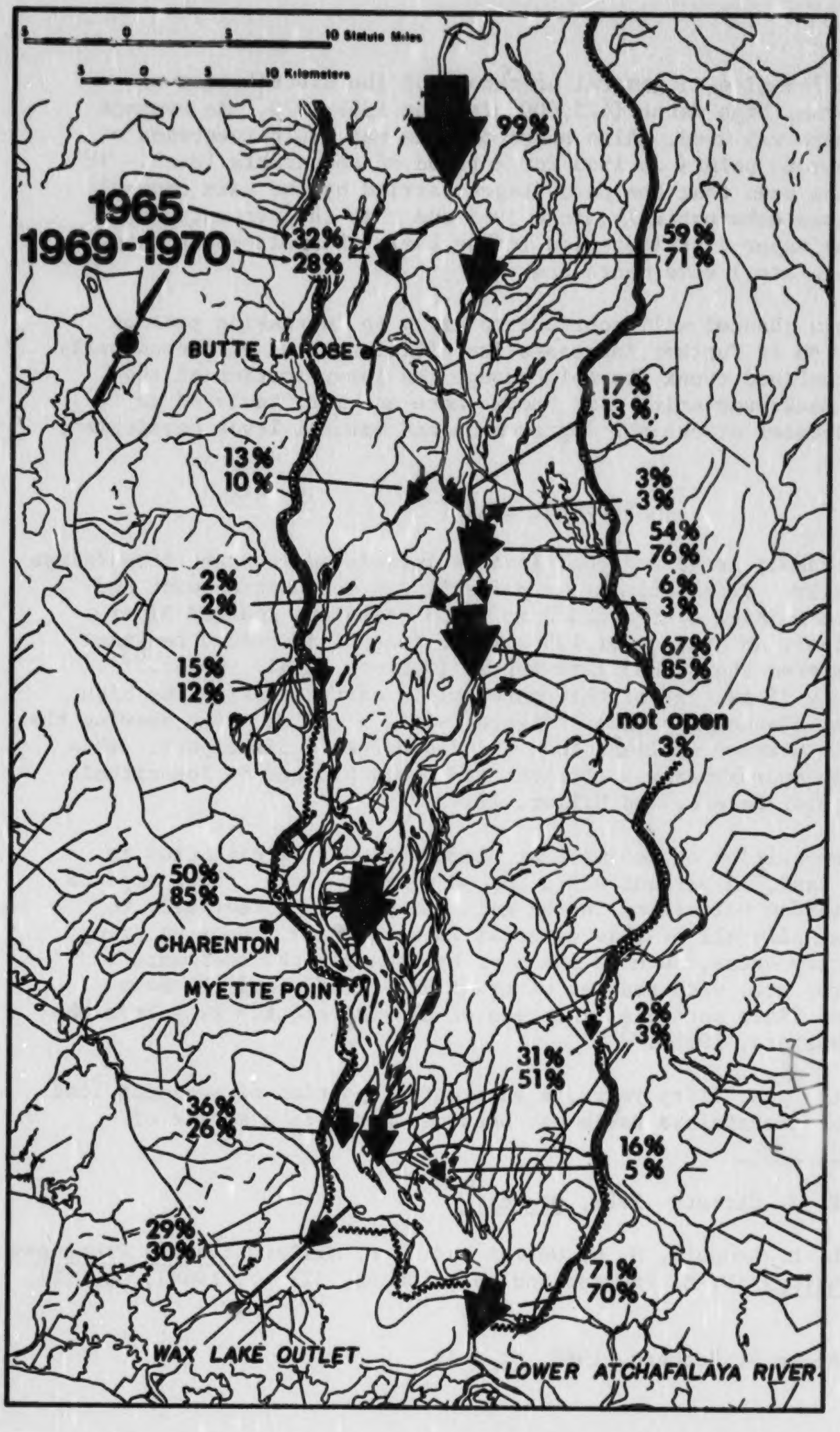
5 0 5 10 Statute Miles
5 0 5 10 Kilometers
99%
1965
1969-1970
32%
28%
59%
71%
BUTTE LAROSE
17%
13%
13%
10%
3%
3%
54%
76%
2%
2%
6%
3%
67%
85%
15%
12%
not open
3%
50%
85%
CHARENTON
MYETTE POINT
2%
3%
31%
51%
36%
26%
16%
5%
29%
30%
71%
70%
WAX LAKE OUTLET
LOWER ATCHAFALAYA RIVER

Figure 7-3. Distribution of flow in the Atchafalaya Floodway at a discharge of 425,000 cfs for 1969-1970.

Figure 7-3 gives a general breakdown of the distribution of flow at average high water (425,000 cfs) for 1969-1970. An average of the 2 years was used. Also shown on this map are percentages of flow at the same points in 1965 for a flood of comparable level. It can easily be seen that the percentages carried by the main channel have increased substantially since 1965 and that the percentages entering the major distributaries (cross basin channels--Lake Long, Bayou Sorrel, etc.) have decreased.

The main channel will continue to carry an increasing portion of the flow as it further increases its efficiency and will eventually develop a confined trunk channel through the lower portion of the floodway. Backswamp units will become more and more isolated as natural processes of channel improvement and natural levee development continue.

Sediment Load

An extremely large sediment load is introduced into the Atchafalaya Basin annually. This sediment is primarily in conjunction with and incorporated in high discharges from the Mississippi and Red Rivers. From 1951-1967, an average of 135 million tons of suspended sediment per year entered the Atchafalaya system (Garrett et al., 1969).[63] Approximately 75 percent of this material is carried during the high water period (January - June). Figure 7-4 is a rating curve showing the relationship between sediment load and discharge at Simmesport. This relationship approximates a straight line when plotted on logarithmic paper (Leopold, Wolman, and Miller, 1964).[64]

The composition of sediment at Simmesport during high flow is 25 percent sand, 35 percent silt, and 40 percent clay. There appears to be sufficient velocities in the main channels (4-8 feet/sec) to carry essentially all of this material in suspension. Upon entering lower velocity areas, such as lakes or backswamps, the sediments begin to drop out, with coarser material deposited along the main channels and finer particles in areas of slower velocity away from the channels (Hubbard, 1968).[65]

Over the past fifty years, a substantial portion of sediment load entering the Atchafalaya Basin has been deposited in a series of

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[63] B. J. Garrett, 1969, op. cit.

[64] L. B. Leopold, M. G. Wolman and J. P. Miller, Fluvial Processes in Geomorphology (W. H. Freeman and Co., London, 522 p., 1964), pp. 119, 152.

[65] Allen S. Hubbard, 1968, op. cit.

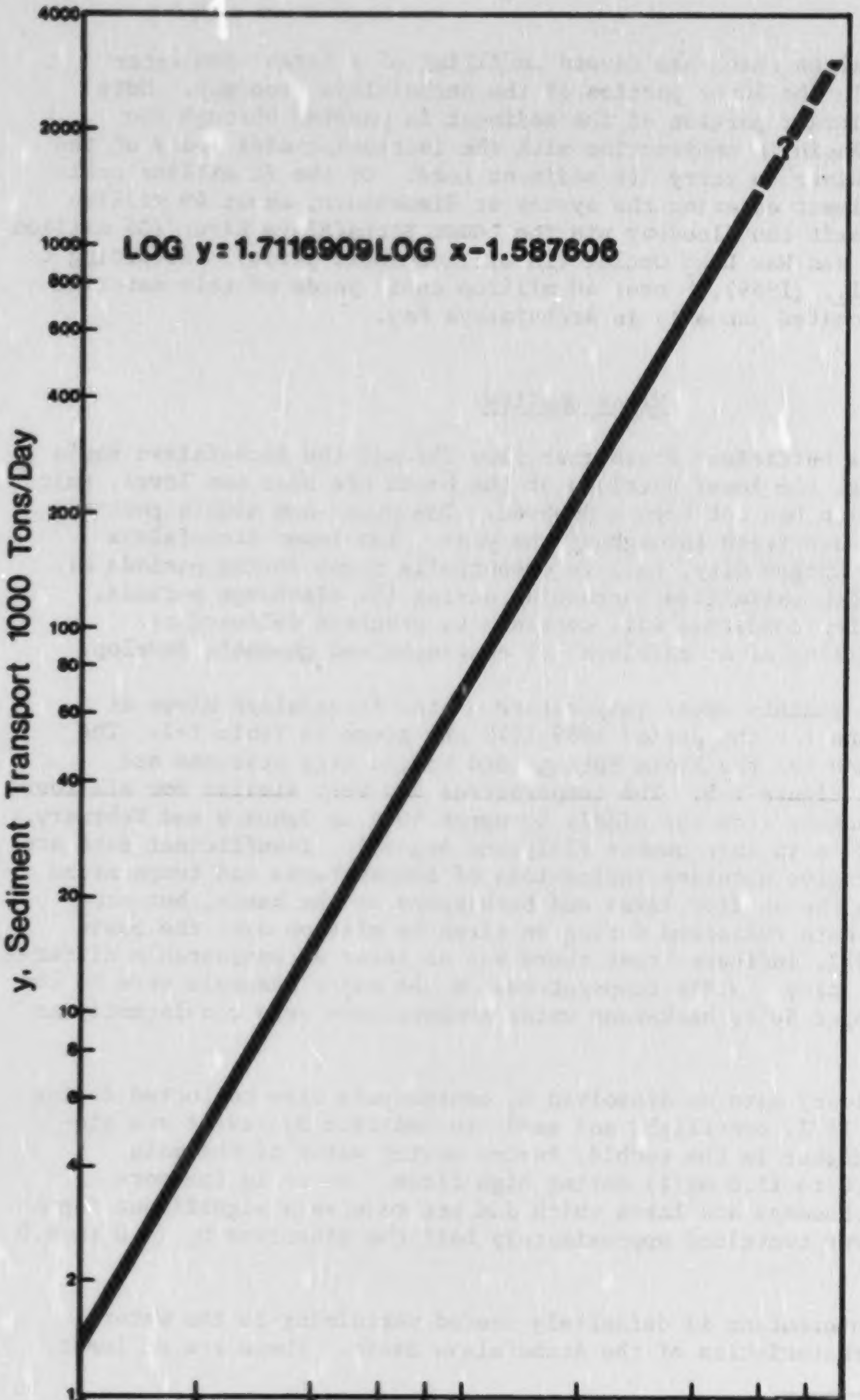

Figure 7-4. **Rating curve showing relationship between suspended load and discharge at Simmesport, Louisiana.**

lacustrine deltas which has caused infilling of a large open water lake system in the lower portion of the Atchafalaya Floodway. More recently, a larger portion of the sediment is passing through the Atchafalaya Basin in conjunction with the increasing efficiency of the Atchafalaya River to carry its sediment load. Of the 72 million cubic yards of sediment entering the system at Simmesport, about 49 million cubic yards exit the floodway via the Lower Atchafalaya River (36 million cubic yards) and Wax Lake Outlet (13 million cubic yards). According to Garrett et al., (1969),[66] over 40 million cubic yards of this material is being deposited annually in Atchafalaya Bay.

Water Quality

There is sufficient freshwater flow through the Atchafalaya Basin that, although the lower portions of the basin are near sea level, salt water intrusion has not been a problem. The upper and middle portions of the basin are fresh throughout the year. The lower Atchafalaya Basin (below Morgan City, La.) is essentially fresh during periods of high flow, with salinities increasing during low discharge periods. This freshwater condition will continue to progress Gulfward as further infilling of Atchafalaya Bay continues and channels develop.

Average monthly water temperature of the Atchafalaya River at four locations for the period 1969-1972 are given in Table 7-1. The plotted values for the Krotz Springs and Morgan City stations are presented in Figure 7-5. The temperatures are very similar for all four stations, ranging from the middle to upper 40's in January and February, to the mid 80's in late summer (July and August). Insufficient data are available to give accurate indications of temperatures and temperature variation in the shallow lakes and backswamps of the basin, but some preliminary data collected during an airphoto mission over the basin in April, 1972, indicate that there was at least a considerable difference at that time. While temperatures in the major channels were in the middle to upper 50's, backswamp water temperatures were consistently in the 70's.

Preliminary data on dissolved O_2 content were also collected during that April, 1972, overflight and seem to indicate O_2 levels are significantly higher in the turbid, faster moving water of the main channels (8.0 to 11.0 mg/l) during high flows. Water in the more stagnant backswamps and lakes which did not receive a significant input from the river contained approximately half the dissolved O_2 (4.0 to 6.0 mg/l).

More information is definitely needed pertaining to the water quality characteristics of the Atchafalaya Basin. There are at least

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[66] B. J. Garrett, 1969, op. cit.

Table 7-1. **Average monthly temperatures of Atchafalaya River water at Simmesport, Krotz Springs, Morgan City and Wax Lake (1969-1972).**

H_2O TEMPERATURES FOR ATCHAFALAYA RIVER

(in degrees Fahrenheit)

4 YEAR AVERAGE MONTH VALUE (1969-1972)

	Simmesport	Krotz Springs	Morgan City	Wax Lake
January	46	46.4	51.3	46.7
February	45	46.4	49.6	47
March	51.3	49.1	56	53.7
April	60.3	55.0	63.7	62.3
May	69.3	67.3	72	70.7
June	78	77.9	78.7	80
July	82.8	85.1	83	84.3
August	83	85.6	84	84.8
September	79.8	84.4	81	83.3
October	69.3	72.7	71	72.5
November	55.5	61.3	59.5	59.5
December	49.5	53.2	53.3	51.5

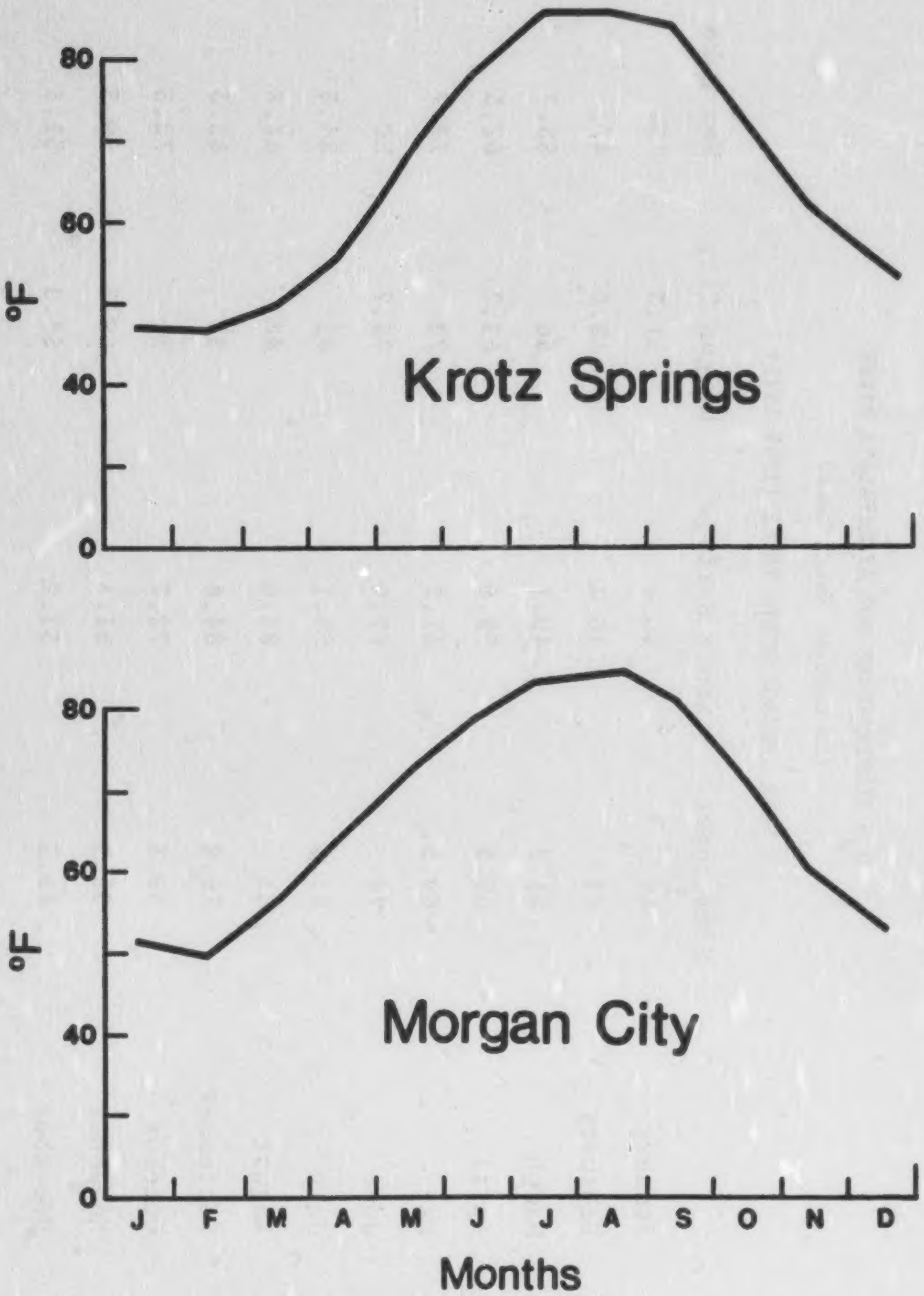

Figure 7-5. Average monthly temperatures of Atchafalaya River water at Krotz Springs and Morgan City, 1969-1972.

two distinctive types of water masses in the basin. The turbid, oxygen-rich water from the Mississippi and Red Rivers which is carried in the main channels is considerably different from the locally generated, or moderated water masses which occupy the more isolated portions of the basin. During falling and low stages, these two masses are easily identified and do not mix unless forced by containment in a common channel. Otherwise, a relatively sharply defined line of contact is usually maintained.

SECTION VIII

LOCAL RUNOFF

Plans for water management in the Atchafalaya Basin require consideration of the existing hydrologic environment, and possible modification of that environment to produce improvements in economic or ecological conditions. The quantity of freshwater generated locally from rainfall is an important parameter of the hydrologic environment. Unfortunately, there are no streamgaging stations in the project area, and no direct measures of that parameter are available. Indirect means have to be employed, based on meteorological records. However, results obtained by such means may be confirmed or adjusted on the basis of available streamflow data in the adjoining region.

In this initial phase of the investigation the interest lies in gross amounts of freshwater over each entire area comprising a management unit. The time frame is one month or longer, and the short-term movement of water and flow distribution is disregarded. The question arises as to whether local runoff can supply the needs for water in the unit. A simple reservoir model is predicted to provide a tentative answer to this question for those management units located within the swamp regions of the project area. This model assumes that the unit under consideration is surrounded by a low dike with a fixed outlet discharging surplus water into a sea level canal.

There are certain constraints to be considered in a water management plan in the Atchafalaya Floodway based on a reservoir system. The dike should be high enough to provide seasonal storage requirements and prevent inflows of heavily silt-laden water from the main channel. Such flood prevention will provide beneficial reduction of the present rate of sedimentation. On the other hand, the crest of the dike should be below water surface elevation limits set by the Atchafalaya Project Flood in order to retain utilization of the management unit as a floodway. The spillway should be designed to allow sufficient dewatering, as well as to maintain an optimum range of water levels in the unit. Salinity control is not important in the project area, and the main object of reservoir regulation is to control sedimentation and water levels in the interest of biological productivity.

Water Budget

The hydrologic cycle, consisting of rainfall, runoff, and evaporation phases, forms the basis for evaluation of the long-term water budget. In this study, rainfall is the measured factor; evaporation is estimated from meterological data; and runoff, or water yield, is the residual between rainfall and evaporation losses corrected, if appropriate, for soil storage. Evaporation is the key unmeasured factor and varies with the type of surface cover. The main distinction in cover lies between an open water or saturated surface and a dry land surface, and an important factor is the ratio of land to water body surfaces within a given area.

Many different approaches are available for estimating evaporation, or transpiration in the case of plant cover, from meterological data. Most of these approaches are restricted to specific regions or types of cover, or require types of measurements not ordinarily available. The Thornthwaite-Mather water balance method (Thornthwaite and Mather, 1955),[67] adopted for this study and similar studies of other portions of the Louisiana coastal regions (Gagliano et. al, 1970),[68] is a well-recognized method with world-wide application utilizing standard data collected at climatological stations.

Potential EvapoTranspiration, abbreviated PET, is a key element in the Thornthwaite-Mather determination. It represents the moisture loss from an evaporating surface drawing on a continuous supply of water. An empirical formula relates this loss to air temperature and a radiation index based on latitude and time of year. Actual EvapoTranspiration, AET, is the reduced rate of moisture loss from a land surface. The ratio of AET to PET depends on the ratio of actual soil moisture in the rooting zone of vegetation to the full moisture capacity in that zone. It ranges from zero at complete soil dryness to unity at saturation.

The Thornthwaite-Mather package includes an algorithm for adjusting soil moisture successively in each time increment. Rainfall amounts are added to antecedent soil moisture in each increment until the capacity is satisfied. Corresponding deductions are made for evaporation computed by means of the formulas previously described until the entire soil moisture is depleted. Rainfall occurring subsequent to soil saturation is assumed to produce runoff. The equivalents to runoff, or rainfall excess, for a lake, bay, marsh, or swamp, are determined by deducting PET from the rainfall amounts.

Water Yield

The procedure outlined in the previous section was used to obtain monthly volumes of water yield during the base period from 1945 through 1970 for the 12 management units. The basic input for these computations consisted of rainfall depths, air temperatures, calendar month, latitude, and land-water ratios. A grid-square method of data organization

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67. C. W. Thornthwaite and J. R. Mather, The Water Balance (Publications in Climatology, VIII, 1955).

68. S. M. Gagliano, R. Muller, P. Light, and M. Al-Awady, Water Balance in Louisiana Estuaries (Report No. 3, Hydrologic and Geologic Studies of Coastal Louisiana, Center for Wetland Resources, L.S.U., Baton Rouge, La., 1970, 98 p.).

(Pentland and Cuthbert, 1971)[69] was adopted to expedite the retrieval of these data for computer operations. An area 10,000-ft^2 was selected as the fundamental geographical data cell; the size representing a compromise between precision and computer economy.

Each cell within the project was assigned an index number, and the indexed data entered on magnetic tape. The data bank formed in this manner covers a total of 1475 cells, as shown in Plate 6.* The sources of the data compiled by cell consisted of USGS topographic quadrangles, aerial photo mosaics, and NWS Climatological Data publications.

Special attention was paid to the compilation of rainfall data because of its importance and variability, and the frequent gaps in the station records. Daily rainfall observations have been collected at 20 stations in or near the project area, as listed in Table 8-1 and located on the map of Plate 6.* Fifteen of these stations have nearly complete monthly records of rainfall during the 26-year base period. These were used as control stations for filling in missing amounts, utilizing a statistical regression procedure, and constructing a 312-month matrix of rainfall data for the 20-station network. This matrix was transformed to a cell matrix utilizing a linear interpolation scheme. In this scheme, rainfall in a cell is estimated from the weighted sum of amounts recorded at three adjacent stations. Weights are assigned inversely proportional to the distances of the station from the cell. The method assumes no systematic effect due to orography, a safe assumption in view of the flat terrain.

The steps of regression and interpolation, performed by computer, are shown diagrammatically in Figure 8-1. These operations feed data into a computer program that performs the Thornthwaite-Mather computations. In these computations, a uniform 6-in. soil moisture capacity is assumed for the terrestrial portion of each cell, based on some measurements made in the clay alluvial soil which is characteristic of the region. Local variations in capacity can be expected due to inhomogeneities of surface cover, but the data are insufficient to define these variations.

Tests were made to verify the water balance method and the assumed soil moisture capacity utilizing available streamflow data. There are two gaging stations located immediately outside the project area that meet the necessary criteria for such tests, namely, long-period records of acceptable quality and absence of diversion or regulation in the watershed area above the station. These are stations located on Bayou Bourbeaux at Shuteston, Louisiana, and Bayou Carencro at Sunset, Louisiana. The respective plots of observed water-year runoff versus

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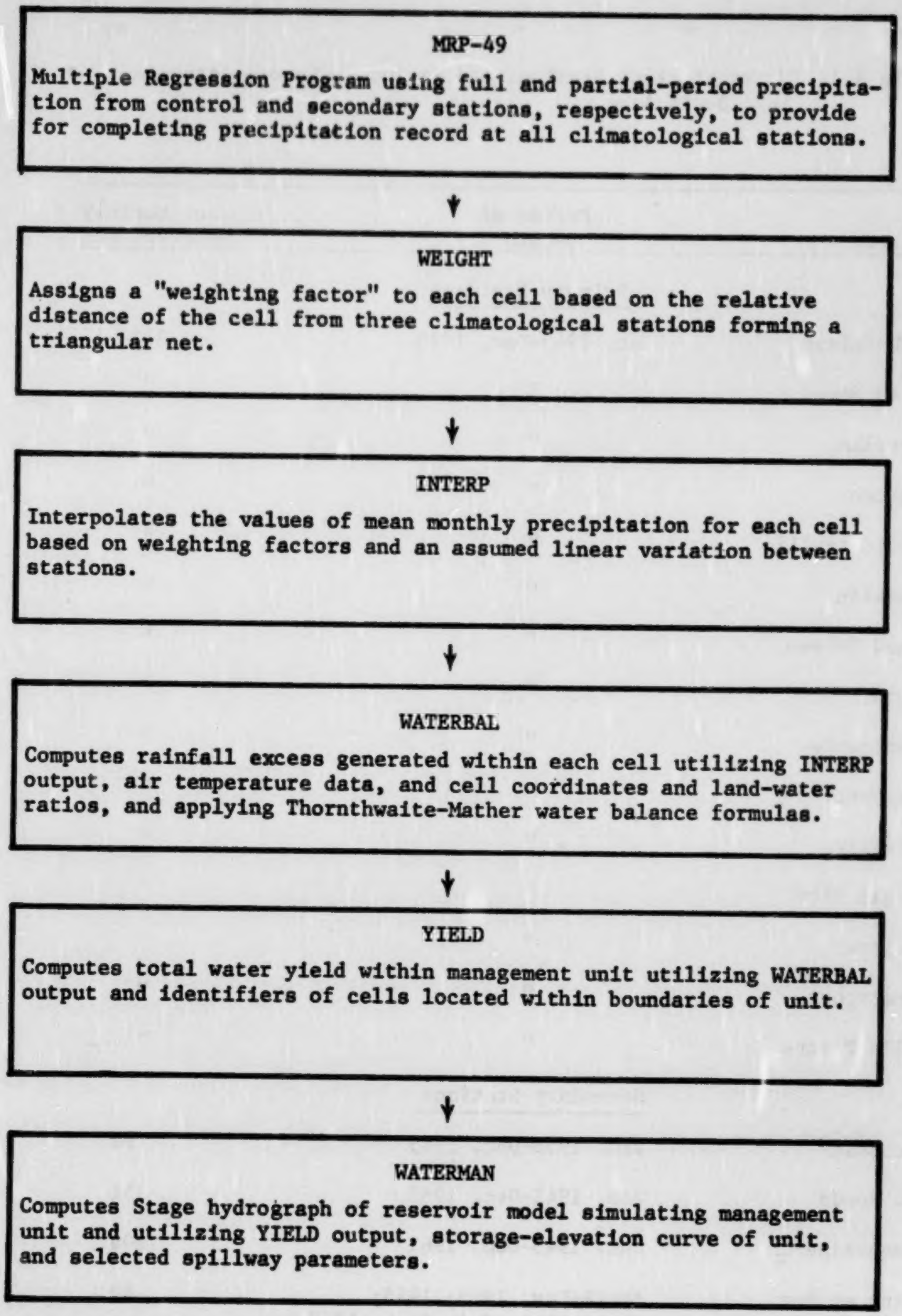
[69] R. L. Pentland and D. R. Cuthbert, Operational Hydrology for Ungaged Streams by the Grid Square Technique (Water Resources Research, AGU, 1971).

* See Apendix C

Table 8-1. Climatological Stations and Period of Record, Atchafalaya Basin Area.

Station	Period of Record	No. Monthly Observations
	Primary Stations	
Atchafalaya	Jan. 1945-Dec. 1970	312
Baton Rouge	"	"
Carville	"	"
Clinton	"	"
Donaldsonville	"	"
Franklin	"	"
Grand Coteau	"	"
Houma	"	"
Jeanerette	"	"
Lafayette	"	"
Melville	"	"
Morgan City	"	"
Shriever	"	"
Simmesport	"	"
Ville Platte	"	"
	Secondary Stations	
Cocodrie	Jan. 1958-Dec. 1965	96
New Roads	Jan. 1945-Dec. 1965	252
Plaquemine	Jan. 1945-Dec. 1961	204
Point au Fer	April-Nov. 1955; 1956; Jan., Mar., July-Sept. 1957; April, June-Dec. 1958; 1960; Jan. 1961	47



MRP-49

Multiple Regression Program using full and partial-period precipitation from control and secondary stations, respectively, to provide for completing precipitation record at all climatological stations.

WEIGHT

Assigns a "weighting factor" to each cell based on the relative distance of the cell from three climatological stations forming a triangular net.

INTERP

Interpolates the values of mean monthly precipitation for each cell based on weighting factors and an assumed linear variation between stations.

WATERBAL

Computes rainfall excess generated within each cell utilizing INTERP output, air temperature data, and cell coordinates and land-water ratios, and applying Thornthwaite-Mather water balance formulas.

YIELD

Computes total water yield within management unit utilizing WATERBAL output and identifiers of cells located within boundaries of unit.

WATERMAN

Computes Stage hydrograph of reservoir model simulating management unit and utilizing YIELD output, storage-elevation curve of unit, and selected spillway parameters.

Figure 8-1. Computer Programs Employed in Processing and Analysis of Hydrologic Data.

runoff computed from water balance are shown for each station in Figures 8-2A and 8-2B. These indicate fairly consistent overestimates of runoff, with average ratios of 81% and 84% between observed and computed runoff. The scatter of points in the two graphs is probably due to a considerable extent to odd distribution of rainfall in some years, errors of observation, and unrepresentativeness of some of the data.

The water yield tables, reproduced from computer printouts in Tables 8-2 through 8-13, are developed with a runoff correction factor of 83%, based on averaging all the water-year tests. The values shown are in units of million cubic feet. Negative values, indicating net moisture deficits, occur during a number of months, mainly in the summer and fall. These represent periods of drought during the warm season of the year when evapotranspiration losses exceed precipitation.

Water Management

As stated previously, a water management scheme is considered here involving the diking of an area and releasing sufficient amounts of runoff generated from local rainfall to maintain water levels within an acceptable range. The Upper Belle River and Buffalo Cove management units have been selected as the pilot areas in this experiment. These units, comprising 203- and 93-mi^2 areas, respectively, are located in the east and west floodways of the lower Atchafalaya River Basin (Plate 3).* The terrain in each case is very flat and poorly drained, with top elevations of 13 feet above sea level. Freshwater swamps cover most of the area included within the two units.

The reservoir model applied in the experiment includes a fixed outlet consisting of a rectangular weir spillway. By varying the dimensions of this spillway and utilizing the model as a simulator on past data, various hydrographs of reservoir elevation can be derived for the base period. These can be compared with the corresponding actual hydrographs, as represented by observed gage-height data for the same period of time. This might offer material to judge the degree of improvement resulting from management control, and lead to a choice between the various control options.

A computer program was developed to perform the simulation based on the simultaneous solution of the storage routing and weir discharge equations in 24-hour steps. One of the inputs to this program, shown as the final stage in the diagram of Figure 8-1, is the spillway length and height of sill selected for the particular trial. A second input is the hypsometric curve of cumulative area vs. elevation, Figures 6-14 and 6-17. The program integrates this curve to provide the relationship between storage volume and elevation required in the routing procedure. The third and last input to the program is the series of water yield values for 1945-1970, listed in Tables 8-8 and 8-11.

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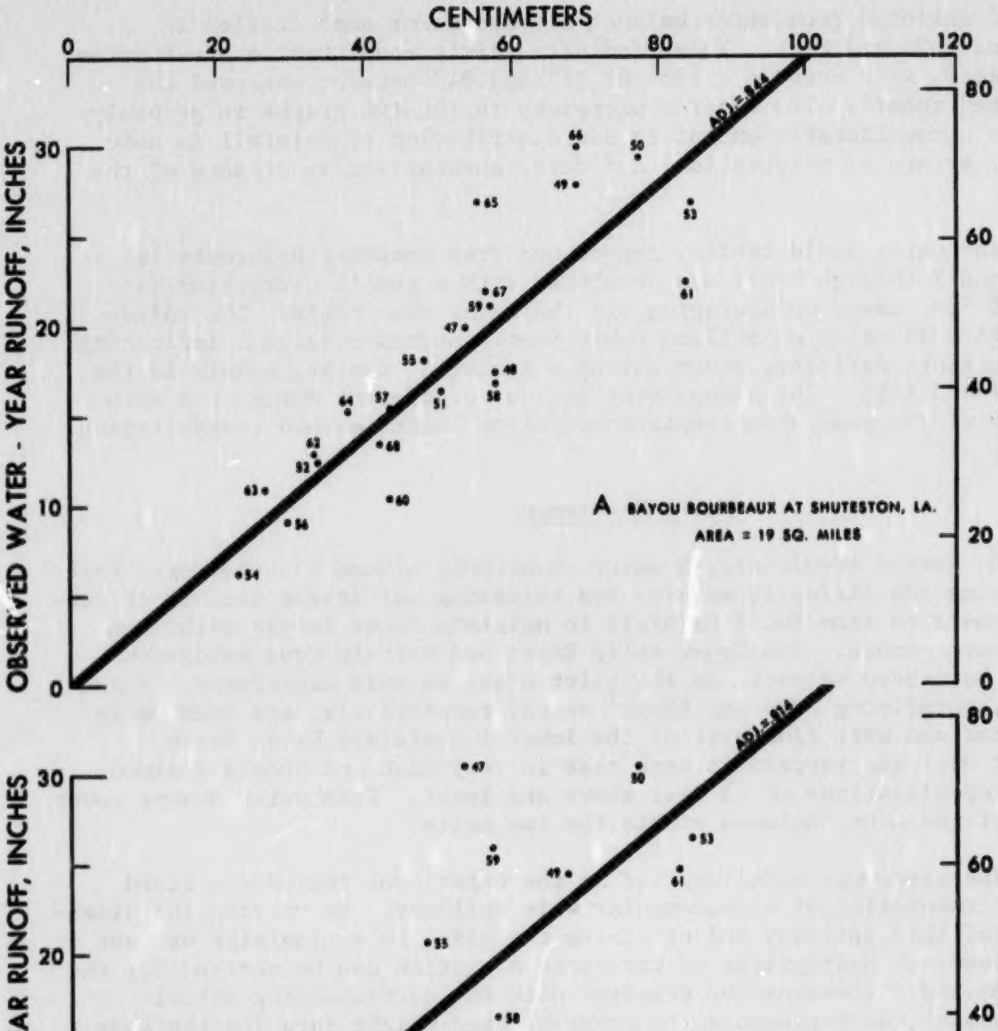
* See Appendix C



Figures 8-2A and 8-2B. Computed and Observed Runoff at Index Streamgaging Stations.

BAYOU FORDOCHE MANAGEMENT UNIT WATER YIELD, MILLION CUBIC FEET

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
1945	1153	1004	2	325	191	-182	-3	-14	-368	374	86	978
1946	1776	777	751	-80	1308	425	1587	-637	-364	-41	898	333
1947	1255	242	2914	524	374	-399	-660	-453	-472	-571	1363	895
1948	1033	1021	727	-103	-530	-826	-794	-477	-164	-70	1580	704
1949	1336	932	1969	530	-431	-285	132	8	-596	735	26	360
1950	1355	765	1380	796	-17	441	-146	-504	-563	-299	116	1425
1951	1375	695	1091	-84	-583	67	-116	-761	619	-400	267	1274
1952	-37	1375	477	1714	343	-809	511	-62	-573	-288	409	1632
1953	721	1691	441	1189	2838	-968	366	794	-794	-309	508	1857
1954	656	181	183	-46	67	-905	656	-803	-569	34	26	388
1955	992	1761	-353	1294	519	-372	106	-282	-541	-216	462	778
1956	373	1356	362	-132	-163	238	-741	-400	-568	-180	605	1501
1957	337	466	851	816	-16	627	-760	-813	814	449	956	917
1958	678	683	807	318	-189	-257	-214	-452	159	-28	-17	319
1959	1257	1752	113	-40	608	-372	594	-451	-361	290	102	1008
1960	864	750	281	133	-214	-864	-668	585	-632	28	31	924
1961	1088	2056	681	252	370	721	583	-387	734	-213	1080	1395
1962	1196	-134	245	753	-572	32	-886	-633	-307	321	163	525
1963	1363	724	-193	-535	-131	-50	-285	-426	-320	-538	548	885
1964	1279	726	1392	-79	-346	-430	275	-281	-123	1665	622	700
1965	280	1064	1170	-487	-372	-511	-285	-437	152	-341	-33	751
1966	2062	2576	-5	1156	95	-654	-24	-93	-244	419	311	310
1967	611	1024	87	285	856	-332	-14	258	-30	198	-157	1351
1968	826	574	464	-119	-360	59	-493	17	-87	-256	1012	1407
1969	380	1251	1351	1488	121	-955	-2	-338	-334	57	-87	740
1970	535	371	806	-229	-139	-231	-134	-483	59	838	314	1003

Table 8-2. Monthly Water Yield in Million Cubic Feet, Bayou Fordoche Management Unit.

WARNER LAKE MANAGEMENT UNIT WATER YIELD, MILLION CUBIC FEET

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
1945	382	348	-29	53	63	-48	-38	48	-93	63	9	254
1946	628	266	316	13	460	265	844	-131	-68	-15	229	92
1947	319	65	952	129	148	-74	-120	-80	-83	-136	367	304
1948	292	286	121	-53	-123	-175	-177	-82	-20	-24	395	211
1949	410	241	592	88	-94	-73	28	-23	-130	93	11	51
1950	368	210	405	238	-31	80	-19	-120	-127	-70	18	373
1951	359	185	319	-35	-136	4	13	-162	114	-92	41	320
1952	-25	452	153	540	69	-187	113	71	-96	-65	61	544
1953	271	493	94	345	682	-210	137	309	-174	-76	137	640
1954	146	56	56	27	-2	-196	200	-172	-96	-8	5	79
1955	302	399	-90	412	243	-73	31	-55	-131	-38	74	146
1956	124	452	35	-38	-45	52	-149	-86	-160	-49	141	428
1957	70	95	292	253	22	142	-211	-171	164	95	298	302
1958	133	255	273	110	-60	-79	-60	-106	-4	-30	-23	51
1959	362	537	11	-55	254	-95	152	-101	-92	71	8	195
1960	249	232	74	43	-52	-196	-105	178	-155	-24	-10	151
1961	312	633	184	56	150	147	198	-50	283	-60	330	573
1962	394	-33	26	257	-144	13	-165	-113	-77	67	26	110
1963	380	219	-50	-131	-26	5	-43	-123	-75	-119	128	229
1964	429	256	442	-20	-97	-78	115	-44	-46	612	178	139
1965	65	331	331	-109	-90	-109	-59	-87	14	-75	-18	175
1966	687	833	5	295	10	-156	63	2	-48	88	62	86
1967	182	310	31	-35	147	-61	-10	82	-30	22	-42	355
1968	262	187	126	-59	-104	2	-94	48	-43	-86	248	470
1969	26	337	447	471	0	-209	17	-61	-85	-7	-29	171
1970	187	114	279	-73	-54	-32	35	-103	13	135	102	299

Table 8-3. Monthly Water Yield in Million Cubic Feet, Warner Lake Management Unit.

BAYOU DES GLAISES MANAGEMENT UNIT WATER YIELD, MILLION CUBIC FEET

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
1945	2025	1849	-89	445	294	-235	-203	84	-507	316	60	1481
1946	3167	1482	1611	-32	2665	1058	3607	-559	-316	-97	1344	580
1947	2181	420	4608	710	642	-311	-638	-406	-347	-646	1800	1784
1948	1794	1479	1295	-191	-595	-738	-874	-406	-18	-176	2212	1138
1949	2031	1260	3159	846	-495	-460	138	-179	-573	497	2	315
1950	2186	1268	2133	1275	-110	497	-108	-642	-642	-340	102	1826
1951	2138	965	1763	-152	-679	-106	-52	-797	479	-448	222	1693
1952	-66	2298	771	2594	595	-516	393	14	-401	-316	397	2576
1953	1314	2627	642	1777	4396	-904	548	1044	-828	-380	715	3296
1954	912	306	342	27	83	-933	815	-844	-468	109	75	422
1955	1624	2392	-421	2226	903	-379	139	-265	-608	-140	392	937
1956	652	2270	503	-139	-266	205	-668	-464	-749	-256	583	2087
1957	406	668	1556	1312	-53	1153	-541	-778	731	645	1648	1549
1958	968	1356	1461	627	-234	-316	-319	-405	89	-149	-83	245
1959	2030	2914	135	-187	1260	-464	670	-468	-466	321	49	1195
1960	1366	1217	433	178	-246	-935	-542	758	-762	-110	-56	1014
1961	1714	3276	1230	355	587	604	907	-274	1320	-304	1822	3177
1962	2139	-138	240	1482	-668	34	-892	-591	-363	278	113	571
1963	2172	1151	-254	-628	-224	7	-162	-592	-381	-563	653	1236
1964	2251	1362	2447	-13	-370	-466	685	-222	-195	2834	1037	937
1965	401	1757	1682	-540	-370	-622	-311	-368	105	-374	-27	864
1966	3544	4450	28	1748	93	-729	194	3	-281	385	207	504
1967	972	1648	151	206	1165	-368	-11	307	-174	109	-202	1847
1968	1316	975	735	-224	-369	-131	-471	213	-260	-422	1113	2480
1969	246	1988	2273	2426	-25	-1012	114	-382	-445	31	-113	843
1970	940	610	1451	-305	-204	-156	6	-443	35	800	518	1525

Table 8-4. Monthly Water Yield in Million Cubic Feet, Bayou Des Glaises Management Unit.

COCODRIE SWAMP MANAGEMENT UNIT WATER YIELD, MILLION CUBIC FEET

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
1945	667	517	-30	102	94	-111	-66	134	-159	105	8	473
1946	902	425	604	-7	688	462	1495	-191	-80	-33	442	171
1947	544	97	1477	251	271	-131	-178	-67	-126	-214	648	520
1948	499	431	337	-74	-208	-315	-284	-100	-8	-59	607	453
1949	551	311	896	234	-183	-46	117	-69	-217	168	-3	170
1950	484	332	562	367	-33	119	28	-204	-205	-132	36	609
1951	630	225	476	-67	-227	-73	148	-297	161	-134	70	428
1952	-23	740	180	836	124	-251	186	-15	-101	-111	115	313
1953	433	717	120	446	357	-336	105	355	-268	-126	269	1065
1954	289	61	57	-10	-25	-281	473	-297	-139	16	24	126
1955	508	712	-154	580	361	-99	53	44	-239	-32	137	255
1956	218	718	64	-53	-70	99	-240	-123	-265	-72	232	772
1957	67	155	592	352	4	345	-324	-293	269	299	448	441
1958	266	451	425	159	-72	-173	-37	-51	-19	-64	-28	81
1959	540	933	27	-69	351	-124	366	-124	-154	206	18	361
1960	371	367	171	107	-130	-301	-122	427	-262	-13	-10	313
1961	507	895	252	47	255	291	301	-92	293	-101	517	1011
1962	579	-64	44	297	-271	72	-235	-137	-139	135	23	213
1963	565	329	-93	-226	-75	21	-79	-200	-95	-204	255	431
1964	686	436	640	-30	-167	-154	250	-36	-58	1213	210	177
1965	157	566	474	-194	-177	-116	-66	-59	42	-108	-38	386
1966	1127	1386	-2	485	-52	-195	123	32	62	205	63	123
1967	288	478	57	-64	190	-88	-11	128	-53	37	-73	532
1968	346	313	190	-110	-147	-48	-123	82	-65	-136	421	736
1969	69	536	665	762	84	-343	102	-131	-124	-4	-48	333
1970	277	185	460	-121	-85	-30	80	-37	64	300	158	448

Table 8-5. Monthly Water Yield in Million Cubic Feet, Cocodrie Swamp Management Unit.

BEAU BAYOU MANAGEMENT UNIT WATER YIELD, MILLION CUBIC FEET

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
1945	444	320	-14	42	59	-105	-61	119	-136	76	2	329
1946	478	265	438	-23	442	293	913	-125	-52	-34	359	115
1947	368	65	877	180	180	-95	-138	-26	-91	-169	489	351
1948	329	247	350	-44	-172	-238	-230	-61	29	-66	470	323
1949	248	142	538	210	-167	-30	127	-69	-162	148	-21	169
1950	288	211	304	256	-15	102	65	-180	-171	-115	33	419
1951	389	104	298	-47	-184	-122	156	-258	113	-97	57	224
1952	1	470	80	489	110	-178	124	-79	-30	-91	112	465
1953	265	395	87	225	551	-245	42	118	-208	-103	256	684
1954	260	30	29	-25	-11	-200	363	-249	-98	67	35	108
1955	337	472	-126	334	152	-72	37	106	-195	-55	119	179
1956	145	427	61	-31	-57	57	-169	-108	-206	-55	169	509
1957	10	94	432	204	-36	296	-236	-226	193	259	289	242
1958	257	311	278	99	-32	-156	-21	36	11	-63	-17	61
1959	322	631	31	-35	246	-92	295	-82	-131	210	17	235
1960	216	225	134	84	-122	-228	-68	353	-219	0	-9	268
1961	312	492	176	16	152	184	151	-32	130	-82	336	789
1962	341	-51	52	150	-225	81	-185	-100	-118	102	10	175
1963	332	198	-81	-185	-91	29	-49	-153	-62	-166	232	325
1964	437	296	379	-11	-123	-148	231	-13	-32	834	109	101
1965	116	383	257	-160	-144	-80	-47	7	50	-82	-22	364
1966	722	906	-3	311	-61	-126	89	119	108	127	5	83
1967	178	290	41	-32	138	-75	8	89	-47	29	-61	345
1968	173	203	117	-85	-87	-82	-85	69	-60	-109	316	452
1969	58	337	381	488	82	-273	121	-131	-98	5	-31	237
1970	161	123	300	-89	-57	-11	50	-35	62	254	89	272

Table 8-6. Monthly Water Yield in Million Cubic Feet, Beau Bayou Management Unit.

PIGEON BAY MANAGEMENT UNIT

WATER YIELD, MILLION CUBIC FEET

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
1945	638	500	-12	-17	87	-149	-103	121	-204	80	-2	483
1946	611	381	657	-52	728	390	1098	-130	-80	-60	528	156
1947	556	111	1216	263	248	-96	-206	-44	-114	-239	688	572
1948	473	334	662	-36	-243	-251	-333	-76	108	-117	762	408
1949	281	170	790	342	-247	-119	173	-88	-186	225	-52	255
1950	505	313	432	457	-14	220	111	-282	-259	-151	50	573
1951	559	148	470	-35	-256	-234	153	-371	143	-129	73	271
1952	42	660	117	662	221	-255	104	-149	25	-126	191	620
1953	368	527	193	329	826	-283	84	47	-292	-145	392	1000
1954	416	59	64	-32	36	-257	415	-354	-123	200	74	204
1955	505	661	-174	447	79	-104	32	125	-250	-19	169	253
1956	207	567	129	-23	-86	0	-174	-196	-262	-78	186	666
1957	-7	122	625	321	-113	476	-288	-269	203	364	470	317
1958	421	484	440	167	-7	-208	-79	98	113	-100	-22	79
1959	475	945	66	-23	454	-148	394	-121	-196	273	15	354
1960	306	319	194	125	-164	-305	-78	388	-315	-4	-22	395
1961	428	682	337	40	188	211	153	-126	209	-114	488	1395
1962	500	-60	125	243	-284	104	-292	-177	-165	92	15	236
1963	475	291	-114	-248	-172	56	-15	-193	-78	-229	335	491
1964	653	450	571	15	-128	-245	305	-25	-23	1079	188	176
1965	194	578	341	-212	-165	-156	-94	56	90	-121	0	510
1966	1052	1337	4	450	-63	-169	70	148	86	155	2	135
1967	257	415	63	16	259	-133	64	134	-74	41	-82	546
1968	235	297	179	-91	-64	-164	-123	93	-113	-160	437	644
1969	101	501	531	730	72	-369	176	-211	-153	36	-19	390
1970	230	192	448	-103	-53	-12	2	-20	55	369	125	410

Table 8-7. Monthly Water Yield in Million Cubic Feet, Pigeon Bay Management Unit.

BUFFALO COVE MANAGEMENT UNIT **WATER YIELD, MILLION CUBIC FEET**

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
1945	1079	705	0	49	91	-363	-194	456	-310	163	-15	854
1946	959	562	1250	7	1247	722	2024	-224	42	-19	909	435
1947	915	182	1739	460	430	-224	-293	-3	-185	-339	1351	1078
1948	792	530	1142	-34	-423	-585	-544	-10	243	-231	1173	919
1949	325	195	1226	667	-437	51	546	-291	-356	413	-84	549
1950	556	497	535	564	-17	251	277	-517	-405	-322	81	955
1951	867	132	681	-73	-440	-440	612	-662	260	-237	153	475
1952	31	1225	139	942	273	-298	325	-378	32	-231	324	892
1953	611	785	225	432	906	-511	-59	146	-503	-242	765	1613
1954	689	15	18	-101	-16	-349	1196	-561	-240	236	142	323
1955	843	1152	-317	615	192	-184	245	617	-464	-157	328	417
1956	379	1019	167	-52	65	-17	-296	-225	-461	-86	337	1222
1957	-51	146	1126	330	-168	864	-480	-456	408	826	825	467
1958	756	787	651	177	-25	-435	68	397	62	-164	-37	129
1959	675	1599	99	-12	672	-243	796	24	-353	678	11	516
1960	436	538	398	290	-347	-453	-87	983	-542	52	-24	739
1961	685	913	348	-36	241	568	149	-132	153	-181	936	1929
1962	689	-139	142	160	-602	324	-461	-166	-186	203	-4	523
1963	668	461	-214	-475	-350	250	-15	-371	9	-423	721	791
1964	1104	815	780	23	-260	-358	851	14	-69	1996	151	204
1965	366	994	446	-417	-392	-229	-111	206	214	-172	-1	1161
1966	1750	2310	-17	652	-261	-235	276	502	471	257	-53	211
1967	473	634	51	-130	374	-240	32	404	-39	85	-157	826
1968	260	506	280	-197	-18	-335	-180	323	-152	-270	875	975
1969	170	759	838	1184	349	-643	478	-307	-182	-14	-71	770
1970	329	288	741	-231	-29	106	135	342	391	688	118	553

Table 8-8. Monthly Water Yield in Million Cubic Feet, Buffalo Cove Management Unit.

FLAT LAKE MANAGEMENT UNIT WATER YIELD, MILLION CUBIC FEET

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
1945	779	606	-4	-72	77	-327	-212	309	-310	116	-14	660
1946	700	418	930	1	1123	488	1164	-182	1	-28	718	323
1947	699	167	1270	325	288	-156	-327	-90	-174	-344	1127	875
1948	574	390	974	-9	-412	-422	-555	-34	314	-241	1132	355
1949	227	149	982	495	-412	-148	402	-239	-283	416	-87	408
1950	592	389	448	538	-27	295	171	-547	-429	-298	75	823
1951	660	141	587	-10	-424	-430	342	-629	271	-243	146	335
1952	47	924	152	667	271	-366	199	-319	66	-219	353	675
1953	447	583	270	404	770	-420	105	18	-516	-236	718	1231
1954	531	43	59	-55	84	-351	794	-535	-237	351	157	313
1955	648	797	-302	529	-11	-211	201	319	-384	-47	308	336
1956	276	721	168	-32	50	-158	-198	-308	-405	-93	252	857
1957	-52	91	774	306	-235	682	-433	-356	293	568	723	339
1958	610	622	549	171	0	-360	-51	284	216	-161	-45	119
1959	543	1214	94	4	691	-312	554	-41	-355	470	-5	419
1960	337	407	270	208	-279	-443	-118	635	-534	11	-46	525
1961	483	726	382	6	130	350	27	-128	275	-172	790	1694
1962	561	-109	192	212	-504	246	-546	-276	-164	90	20	458
1963	522	374	-200	-437	-373	264	75	-334	-3	-399	654	590
1964	876	641	659	61	-180	-374	675	-42	-55	1241	192	219
1965	314	772	330	-374	-299	-370	-189	174	221	-196	57	864
1966	1328	1771	4	474	-157	-292	171	306	137	172	-34	199
1967	370	487	32	-42	395	-293	104	332	-104	82	-143	755
1968	221	382	234	-135	46	-339	-217	308	-199	-281	754	732
1969	145	594	649	932	154	-610	384	-302	-217	6	-31	616
1970	261	235	574	-195	9	84	-6	257	233	539	89	463

Table 8-9. Monthly Water Yield in Million Cubic Feet, Flat Lake Management Unit.

THE CREVASSE MANAGEMENT UNIT   WATER YIELD, MILLION CUBIC FEET

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
1945	531	388	3	0	0	-262	-113	323	-96	81	-11	452
1946	561	239	744	156	935	389	778	-121	171	84	428	396
1947	477	132	706	223	168	-128	-160	-69	-91	-131	871	768
1948	395	272	648	15	-230	-321	-269	34	249	-145	727	498
1949	143	98	700	365	-202	32	356	-217	-142	229	-20	311
1950	287	266	251	258	-27	126	107	-332	-212	-183	25	477
1951	435	77	392	29	-212	-185	317	-320	225	-172	105	204
1952	-24	805	138	351	137	-154	236	-161	-39	-128	183	418
1953	324	409	151	318	187	-235	15	86	-310	-120	481	873
1954	357	-6	-1	-30	38	-149	831	-217	-173	78	91	207
1955	466	514	-176	294	21	-165	339	350	-170	-103	181	255
1956	223	613	78	-32	281	-143	-75	-93	-189	-9	131	581
1957	-37	23	504	100	-96	356	-235	-130	187	403	644	239
1958	426	405	350	55	-27	-204	109	211	65	-65	-37	63
1959	322	856	52	14	544	-221	359	191	-216	299	-17	260
1960	204	330	204	212	-140	-203	-94	463	-276	18	-26	378
1961	322	476	156	-44	-5	391	-62	53	178	-66	748	798
1962	337	-78	81	41	-333	194	-317	-101	24	26	7	351
1963	308	287	-109	-265	-225	314	100	-211	109	-235	492	364
1964	701	539	403	51	-108	-113	672	-33	-74	781	73	142
1965	278	583	169	-227	-204	-286	-106	102	168	-96	56	691
1966	965	1351	-2	227	-133	-197	210	273	133	135	-36	164
1967	333	331	-29	-171	274	-201	-17	462	-26	66	-85	526
1968	107	284	172	-78	122	-181	-120	341	-93	-155	563	459
1969	103	371	498	647	216	-334	264	-74	-76	-83	-40	401
1970	169	143	411	-138	74	150	58	449	356	365	0	255

Table 8-10. Monthly Water Yield in Million Cubic Feet, The Crevasse Management Unit.

UPPER BELLE RIVER MANAGEMENT UNIT WATER YIELD, MILLION CUBIC FEET

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
1945	2184	1798	106	17	-139	-1578	-126	1620	-234	327	-106	1626
1946	2369	1174	2977	705	4085	1770	2840	-634	1215	114	1862	1630
1947	2067	591	2643	897	414	-909	-1043	-77	-412	-779	4319	3456
1948	1713	916	2685	65	-1338	-1646	-1173	-205	2081	-716	3186	2028
1949	501	425	2784	1546	-1015	-196	1301	-803	-133	997	-162	1364
1950	1129	1000	1002	1302	-128	475	495	-1542	-1146	-892	113	2401
1951	1749	375	1723	334	-828	-990	1458	-1441	1424	-873	699	879
1952	-95	3278	497	1401	717	-1202	1138	-417	-145	-647	926	1757
1953	1157	1743	623	1354	69	-1009	217	146	-1580	-596	2339	3833
1954	1381	-21	-43	-138	527	-940	2889	-959	-800	409	462	993
1955	1928	1637	-892	1280	-160	-1134	1763	1178	-424	-551	907	1111
1956	943	2578	427	-47	947	-391	-287	-413	-466	158	522	2617
1957	-170	358	1996	792	-434	1365	-1135	-155	837	1364	2553	1047
1958	1958	1434	1532	177	50	-958	617	689	460	-270	-157	382
1959	1170	3440	253	35	2220	-952	1489	764	-932	1427	-21	1116
1960	873	1492	629	1040	-328	-1119	-801	1737	-1254	63	-161	1635
1961	1506	2372	754	-213	-301	1811	-338	504	997	-164	3359	2839
1962	1546	-412	464	333	-1752	889	-1309	-663	60	169	80	1700
1963	1167	1302	-483	-1303	-1137	1983	170	-914	568	-1189	2630	1558
1964	3056	2333	1707	348	-614	-597	3393	-276	-379	2866	360	682
1965	1141	2422	600	-1039	-752	-1556	-370	523	961	-502	454	2844
1966	3981	5221	-19	1058	-329	-1165	982	1003	243	630	-190	816
1967	1397	1469	-179	-1106	1293	-1217	-355	1786	74	348	-391	2724
1968	408	1182	677	-142	336	-797	-347	1222	-415	-559	2301	1833
1969	481	1423	2180	2214	1027	-1569	1014	-225	-633	-558	-225	1721
1970	708	522	1695	-899	386	251	116	1465	1427	1412	-43	984

Table 8-11. Monthly Water Yield in Million Cubic Feet, Upper Belle River Management Unit.

WATER YIELD. MILLION CUBIC FEET

YELLOW BAYOU MANAGEMENT UNIT

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
1945	61	46	3	0	-5	-35	-11	54	-8	8	-2	48
1946	74	27	94	30	132	52	97	-14	41	16	44	59
1947	56	19	57	22	17	-19	-17	-5	-10	-11	118	108
1948	45	31	73	5	-27	-41	-30	9	44	-16	78	66
1949	15	10	84	46	-20	8	51	-28	-13	27	0	40
1950	28	30	22	23	-4	11	17	-38	-21	-22	2	56
1951	48	7	46	6	-23	-16	53	-33	32	-22	13	23
1952	-5	107	16	31	4	-17	39	-16	-5	-15	19	44
1953	35	49	17	40	-3	-26	2	14	-37	-12	64	102
1954	39	-4	-2	-1	4	-15	111	-16	-24	0	10	24
1955	55	57	-20	26	4	-24	57	50	-16	-17	22	31
1956	28	78	8	-3	49	-19	-6	-5	-18	4	11	69
1957	-4	0	55	8	-8	39	-25	-6	22	51	85	25
1958	50	44	41	0	-4	-24	20	29	-1	-3	-4	6
1959	33	100	6	1	65	-24	37	37	-23	39	-4	27
1960	22	40	23	29	-12	-18	-14	57	-30	4	-3	45
1961	38	52	4	-8	-7	60	-16	12	19	-4	97	60
1962	37	-10	5	1	-41	28	-34	-10	10	4	1	48
1963	29	37	-12	-32	-29	57	13	-25	23	-27	70	38
1964	87	69	43	8	-14	-8	106	-3	-11	84	4	15
1965	39	70	14	-26	-25	-37	-11	13	23	-9	11	89
1966	115	162	-1	23	-17	-25	28	38	17	18	-4	23
1967	44	38	-8	-29	35	-29	-9	65	4	11	-9	68
1968	9	35	21	-5	19	-17	-13	52	-5	-14	72	47
1969	13	40	64	72	38	-36	35	3	-6	-17	-7	46
1970	18	14	49	-22	14	24	14	78	60	44	-5	22

Table 8-12. Monthly Water Yield in Million Cubic Feet, Yellow Bayou Management Unit.

WATER YIELD. MILLION CUBIC FEET

SIX MILE LAKE MANAGEMENT UNIT

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
1945	468	404	56	6	-64	-302	-21	414	-55	48	-37	308
1946	546	278	666	202	1008	427	797	-110	379	41	368	394
1947	449	161	393	153	91	-186	-169	48	-83	-144	945	836
1948	350	195	567	42	-251	-321	-247	4	489	-118	564	485
1949	99	81	603	363	-164	-23	299	-146	-19	210	-24	316
1950	227	202	166	244	-29	95	178	-251	-181	-167	23	479
1951	362	61	371	72	-177	-146	427	-257	304	-155	125	171
1952	-9	744	77	266	19	-223	272	-78	18	-120	153	347
1953	219	387	123	292	-77	-180	55	31	-291	-101	501	809
1954	271	-24	-18	-22	78	-171	618	-123	-167	51	80	190
1955	404	367	-164	177	-5	-225	403	325	-90	-132	183	245
1956	211	551	86	-2	225	-54	-73	-63	-96	67	64	569
1957	-26	37	419	181	-72	253	-182	13	162	339	581	184
1958	407	287	345	-18	-5	-192	135	196	8	-20	-24	65
1959	234	731	61	2	412	-121	260	203	-127	355	-13	221
1960	192	306	126	230	-42	-165	-164	379	-237	52	-34	342
1961	345	468	41	-54	-54	485	-104	66	164	-18	651	426
1962	320	-83	40	68	-335	210	-202	-143	6	85	18	353
1963	202	305	-93	-253	-245	515	-4	-166	157	-221	610	312
1964	634	502	346	81	-142	-130	872	-29	-63	610	53	118
1965	288	517	109	-195	-143	-247	-58	135	191	-78	130	623
1966	856	1095	-13	272	-73	-205	156	260	100	156	-31	181
1967	306	302	-56	-232	270	-261	-126	343	96	98	-69	610
1968	72	264	146	16	54	-92	-61	268	-8	-63	487	355
1969	116	301	496	446	328	-266	243	37	-104	-126	-61	327
1970	137	101	374	-184	86	82	99	465	422	326	-41	165

Table 8-13. Monthly Water Yield in Million Cubic Feet, Six Mile Lake Management Unit.

The results of a single water management trial for each pilot unit are shown in the reproduced printout copies of Tables 8-14 and 8-15. The values shown in the tables result from time-averaged computations and represent mean monthly stages in feet. The initial stage for the calculation is set at sill height on September 30, 1945. The first 12 months thereafter represent a warmup period required to stabilize the computations, so the period of valid output is considered to run from October 1946 to December 1970.

The modification just described leads to a greater stability of water levels, as indicated in the 1967 example for the Upper Belle unit plotted in Figure 8-3. The curves labelled "modified" show a variation of 0.7 ft in elevation and 19% in wetted area during 1967 against a corresponding range of 2.0 ft and 78% under existing conditions for the same year. The latter figures are based on daily gage-height observations at the Intracoastal Waterway near Pierre Pass, a station centrally located latitudinally in the Upper Belle River management unit.

It would be difficult to specify at this time the exact water level and the degree of fluctuation of that level that would be most beneficial to fish and wildlife. When the biological optima are defined, it might be necessary to obtain a more flexible control of water levels within the unit by modifying the hydrologic model. This could be done by substituting a gated outlet for the fixed spillway and/or including diversion of supplementary water from the main channel of the Atchafalaya or an adjacent unit. It should be emphasized, however, that any final decision on a management option should involve consideration of social as well as technological factors.

```
CONTROLLED WATER LEVELS. UPPER BELLE. 1945-70                     203.00 SQUARE MILES
ELEVATION IN FEET VS. STORAGE IN MCF
    0.0      0.0      0.5   353.7      1.0    756.9      1.5  1329.9      2.0  2433.5      2.5  4230.3
    3.0   6554.8      3.5  9175.2      4.0  11842.1      4.5 14551.5      5.0 17289.2      5.5 20341.0
    6.5  25573.0      7.0 28360.2      8.0  33985.6      9.0 39639.2
SH=    2.0
SL= 100.0
1945     0.0      0.0      0.0      0.0      0.0      0.0      0.0      0.0      0.0     3.56     3.30     3.23
1946     3.37     3.43     3.54     3.56     3.70     3.85     3.88     3.68     3.44     3.29     3.26     3.35
1947     3.44     3.40     3.45     3.48     3.33     3.06     2.70     2.50     2.37     2.16     2.59     3.24
1948     3.46     3.42     3.49     3.44     3.08     2.62     2.20     2.00     2.27     2.38     2.63     3.04
1949     3.09     3.00     3.14     3.32     3.13     2.84     2.83     2.74     2.55     2.57     2.55     2.63
1950     2.79     2.87     2.93     3.00     2.94     2.83     2.80     2.56     2.16     1.80     1.63     2.11
1951     2.60     2.72     2.83     2.89     2.70     2.40     2.43     2.34     2.32     2.33     2.28     2.45
1952     2.47     2.76     2.99     3.01     3.04     2.81     2.70     2.66     2.52     2.34     2.35     2.61
1953     2.81     2.97     3.03     3.05     3.00     2.75     2.57     2.54     2.27     1.93     2.20     2.86
1954     3.19     3.11     2.92     2.76     2.70     2.55     2.69     2.76     2.47     2.37     2.43     2.54
1955     2.76     2.99     2.88     2.80     2.78     2.53     2.55     2.76     2.72     2.52     2.50     2.64
1956     2.75     2.99     3.09     2.95     2.89     2.80     2.62     2.46     2.28     2.21     2.28     2.62
1957     2.76     2.67     2.82     2.95     2.83     2.81     2.69     2.47     2.49     2.66     2.95     3.12
1958     3.21     3.30     3.34     3.25     3.07     2.80     2.66     2.70     2.71     2.53     2.50     2.46
1959     2.57     2.95     3.12     2.97     3.04     2.97     2.88     2.96     2.78     2.73     2.75     2.76
1960     2.84     2.94     2.99     2.99     2.89     2.61     2.30     2.40     2.38     2.19     2.16     2.35
1961     2.65     2.94     3.07     2.94     2.75     2.80     2.81     2.71     2.76     2.72     2.95     3.34
1962     3.48     3.30     3.10     3.00     2.69     2.53     2.38     2.08     2.00     2.03     2.06     2.30
1963     2.59     2.76     2.71     2.41     2.04     2.17     2.42     2.26     2.19     2.07     2.28     2.71
1964     3.05     3.35     3.46     3.37     3.11     2.82     2.98     3.09     2.85     2.98     3.10     3.02
1965     3.03     3.19     3.25     2.99     2.67     2.30     2.02     2.05     2.24     2.26     2.24     2.61
1966     3.17     3.76     3.82     3.57     3.35     2.98     2.83     2.89     2.87     2.82     2.74     2.70
1967     2.82     2.97     2.93     2.65     2.60     2.50     2.25     2.42     2.56     2.53     2.45     2.65
1968     2.85     2.88     2.92     2.82     2.72     2.57     2.36     2.43     2.46     2.27     2.47     2.83
1969     2.91     2.96     3.14     3.33     3.38     3.08     2.87     2.81     2.60     2.39     2.24     2.41
1970     2.62     2.66     2.79     2.73     2.59     2.57     2.54     2.63     2.83     2.97     2.94     2.89
```

Table 8-14. Water levels in Upper Belle River unit as computed for assumed managed condition.

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CONTRCLLED WATER LEVELS. BUFFALO COVE. 1945-70                  91.34 SQUARE MILES
ELEVATION IN FEET VS. STORAGE IN MCF
     1.0       0.0       4.0    286.5      4.5    369.2      6.0   1429.2      6.6   2208.4      7.5   3617.8
     8.0    4521.8       8.5   5473.5      9.1   6676.7     10.0   8607.5     11.0  10854.7     11.5  12010.1
    12.0   13213.3      12.6  14718.3
SH=    6.0
SL=   50.0
1945      0.0      0.0      0.0      0.0      0.0      0.0      0.0      0.0      0.0      9.38     8.39     7.92
1946      7.82     7.68     7.69     7.51     7.47     7.56     7.83     7.70     7.21     6.91     6.98     7.10
1947      7.21     7.18     7.43     7.57     7.38     7.06     6.67     6.44     6.29     6.05     6.43     7.05
1948      7.29     7.30     7.42     7.30     6.84     6.34     5.77     5.40     5.57     5.57     6.09     6.78
1949      6.94     6.87     7.09     7.31     7.01     6.69     6.73     6.63     6.28     6.28     6.33     6.45
1950      6.70     6.85     6.95     7.03     6.92     6.79     6.77     6.51     6.10     5.67     5.51     6.11
1951      6.71     6.82     6.88     6.84     6.49     6.09     6.16     6.07     5.90     5.90     5.86     6.12
1952      6.24     6.64     6.87     6.99     7.07     6.80     6.66     6.48     6.28     6.16     6.19     6.58
1953      6.89     7.07     7.07     7.00     7.14     6.93     6.58     6.49     6.26     5.91     6.15     6.90
1954      7.28     7.13     6.87     6.65     6.48     6.26     6.53     6.57     6.20     6.18     6.29     6.41
1955      6.71     7.11     7.03     6.89     6.91     6.70     6.59     6.73     6.59     6.27     6.30     6.51
1956      6.65     6.92     7.01     6.81     6.65     6.52     6.30     6.08     5.64     5.27     5.45     6.29
1957      6.60     6.51     6.81     7.01     6.81     6.85     6.74     6.28     6.24     6.62     6.96     7.08
1958      7.15     7.28     7.33     7.19     6.93     6.58     6.37     6.47     6.52     6.38     6.24     6.24
1959      6.49     7.07     7.22     6.94     6.93     6.81     6.82     6.85     6.56     6.58     6.65     6.69
1960      6.81     6.91     6.96     6.92     6.69     6.28     6.06     6.39     6.42     6.19     6.17     6.42
1961      6.77     7.05     7.12     6.93     6.78     6.85     6.85     6.67     6.54     6.41     6.60     7.29
1962      7.59     7.28     6.97     6.83     6.50     6.33     6.21     5.93     5.68     5.70     5.84     6.11
1963      6.51     6.74     6.64     6.27     5.88     5.83     5.99     5.71     5.46     5.16     5.40     6.24
1964      6.80     7.14     7.28     7.15     6.80     6.44     6.54     6.68     6.52     7.01     7.29     7.06
1965      6.97     7.13     7.22     6.90     6.46     6.17     6.03     6.07     6.21     6.19     6.11     6.51
1966      7.24     7.93     7.87     7.54     7.20     6.78     6.64     6.74     6.85     6.86     6.72     6.62
1967      6.70     6.87     6.85     6.64     6.60     6.50     6.34     6.44     6.44     6.36     6.27     6.47
1968      6.70     6.78     6.83     6.66     6.46     6.24     6.03     6.09     6.13     5.92     6.19     6.76
1969      6.89     6.96     7.17     7.42     7.42     6.94     6.72     6.59     6.32     6.20     6.14     6.39
1970      6.66     6.70     6.85     6.78     6.55     6.46     6.46     6.53     6.65     6.83     6.86     6.87
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Table 8-15. Water levels in Buffalo Cove Unit as computed for assumed managed condition.

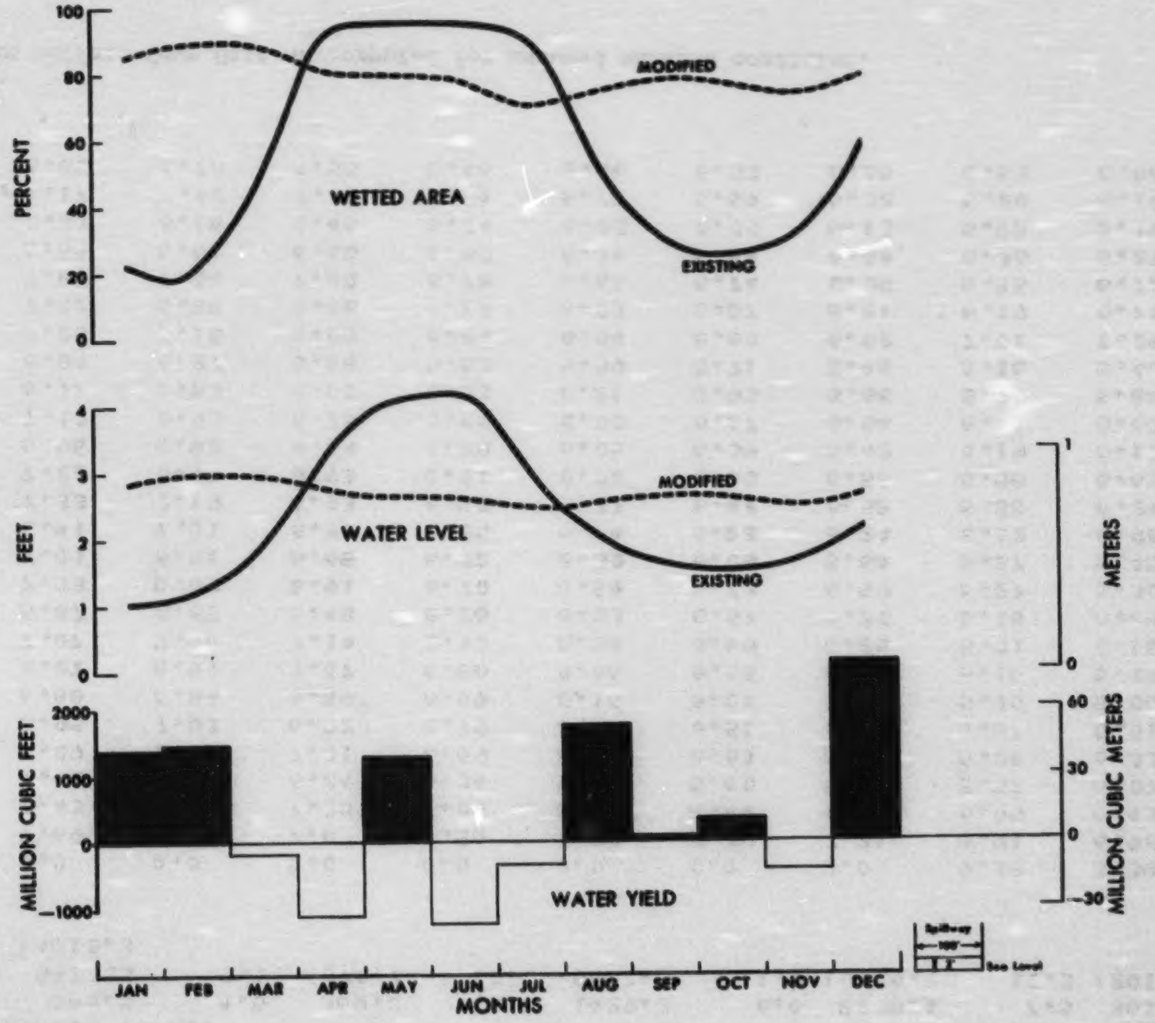

Figure 8-3. Existing and Modified 1967 Environment, Upper Belle River Management Uni

SECTION IX

BASIN HYDROLOGY

Any management plan for the basin will necessarily revolve around effective control of movement and levels of surface water and the associated movement of sediment. An understanding of how the basin operates as a hydrologic system is therefore essential. Basin hydrology should be viewed against the background of previous chapters. Here again it is necessary to separate the Atchafalaya River and its main distributaries from the adjacent floodbasins or overflow swamps. They are separate though interdependent components of the hydrologic system. The main function of the river and its distributaries is to move water and sediment through the system following input from the Mississippi and Red Rivers and from local runoff. In contrast, the overflow swamps must be considered mainly as receiving and storage basins.

River input into the basin as a whole was discussed in the foregoing chapter. Its characteristics are dependent on external factors, but both its maximum value and distribution through the basin can be made subject to control. This concerns, in particular, the volume of water that enters the overflow swamps and the manner in which this occurs. Therefore, in the present chapter, emphasis is placed on the relationship between the channel and the overflow swamp subsystems.

Overflow and Throughflow

Ideally, the channels and floodbasins are linked through an overflow process in which topography acts as a regulator. This can best be illustrated conceptually by viewing the basin as a series of pan-shaped depressions separated from each other by channels and their associated natural levee ridges. As shown in Figure 9-1, these depressions or floodbasins occur in two arrays along the main channel. Corresponding to the overall seaward slope of the basin, floodbasins within each array are stepped in the direction of the main channel. Furthermore, they are separated from each other as a result of natural levee building along major distributaries of the main channel. Enclosure of each floodbasin is complete where a low levee has developed along the marginal channels which collect and redirect down the basin flow diverted through the distributary channels. The above conditions are illustrated schematically across and along the main channel in the upper and lower cross-section of Figure 9-1, respectively.

Given time, natural levees tend to develop to the point where crest elevation coincides with approximately the level of bankfull stage, or the stage generally accepted to be associated with the flood

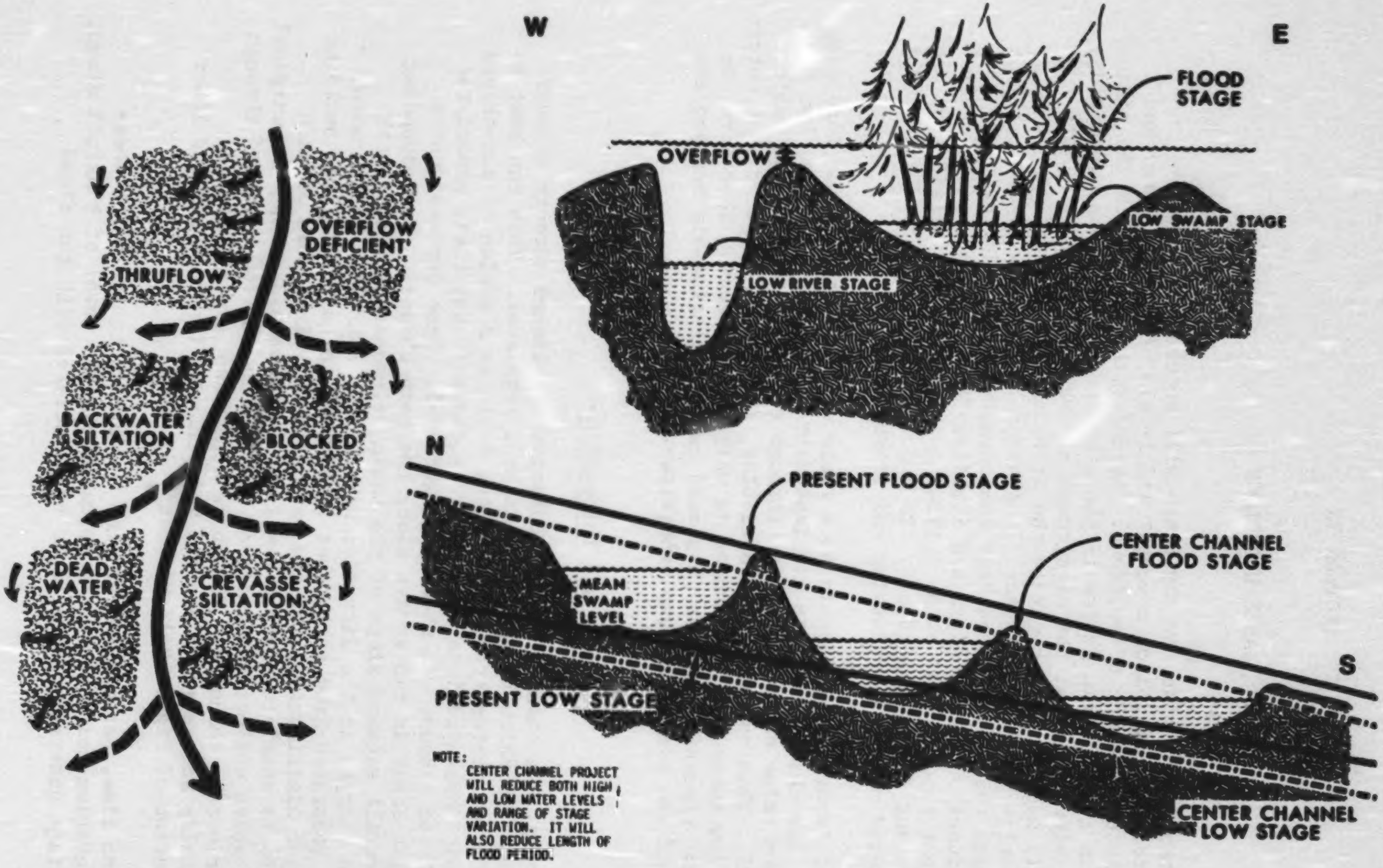
W
E
FLOOD STAGE
OVERFLOW
LOW SWAMP STAGE
LOW RIVER STAGE
THRUFLOW
OVERFLOW DEFICIENT
BACKWATER SILTATION
BLOCKED
DEAD WATER
CREVASSE SILTATION
N
S
PRESENT FLOOD STAGE
CENTER CHANNEL FLOOD STAGE
MEAN SWAMP LEVEL
PRESENT LOW STAGE
CENTER CHANNEL LOW STAGE
NOTE:
CENTER CHANNEL PROJECT WILL REDUCE BOTH HIGH AND LOW WATER LEVELS AND RANGE OF STAGE VARIATION. IT WILL ALSO REDUCE LENGTH OF FLOOD PERIOD.

Figure 9-1. Schematic cross-section and longitudinal section showing the interrelationship of basin channels, floodbasins, depressions, and their associated natural levee ridges.

(Leopold, Wolman, and Miller, 1964),[70] having a probability of occurrence of 0.66 percent. Thus, on the average, individual floodbasins would receive input from the river through overbank flooding once every 1.5 years. Since this input is derived from the upper part of the channel water column, where bedload is absent and the concentration of suspended sediment is relatively low, a minimum of sediment will enter the floodbasins under these conditions. Sediment introduction is further restricted by the reduction of flow velocities as water moves across the vegetated natural levee. The main influx of sediment will occur where local drainage channels leading from the basin provide an opening through the natural levee. Generally, however, these channels are shallow, and flow velocities are low as compared to those in the main channels and distributaries. Though providing for water input, these drainage channels allow only a limited influx of sediment, most of which is deposited near the mouth and a natural levee that decreases in height toward the basin center.

During rising river stage, water in the floodbasin will also rise, but here stages lag behind those of the river as a result of time involved in water transfer from the channels into the basins. Related to basin slope and an increase in hydraulic gradient with rising stage, water in the floodbasins becomes increasingly subject to movement from the upper to the lower end. Ideally, there is a net flow with floodwater percolating through each basin. This process replenishes the oxygen and basic nutrient supply of the overflow swamp and plays a major role in maintaining biological productivity.

During falling stage in the channels, water drains from the basins. Circulation of water, thus, is maintained for some time. The enclosed nature of the overflow swamp and the low gradient of its drainage channels cause water levels in the basin to fall more slowly than those in the channels, and allow the swamp to retain water during low river stages.

Deviations

From information provided by commercial and sports fishermen, as well as fisheries biologists, it appears that basins in which the above described conditions prevail are the most productive. Deviations from those conditions generally bring about a decline in productivity. Such deviations may occur for different reasons. Based on association of changes in the hydrologic operation of certain areas and a following decline in productivity, some of these reasons can be identified. They are schematically illustrated in the left-hand diagram in Figure 9-1. Each of the reasons represents either an interruption of the overflow and throughflow regime or an excessive influx of sediment. The overflow regime is disrupted where natural levee elevations become too high to allow regular overbank flooding. This may occur when flow distribution changes and bankfull stages no longer are coincident with the natural levee crest height, or as a result of spoil deposition on the levee when channel maintenance involves massive dredging.

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[70] L. B. Leopold, et. al., 1964, op. cit.

The above condition may, in turn, lead to a second problem, that of backwater siltation. A lack of inflow in the upper part of a basin appears to enhance an excessive inflow of water from the lower end. Related to natural levee and stage elevations, such backwater inflow tends to promote excessive accumulation of silt along the lower end of the basin. The resulting increase in surface elevations further aggravates the problem as it impedes the already reduced throughflow.

A similar situation is created where water enters a basin predominantly from the sides and lower end. This greatly tends to reduce throughflow, and it creates a dead water area in the upper and central lower parts of the basin.

A common cause for a decrease in basin throughflow is the interruption of internal drainage. In most cases, this appears to occur as a result of either excessive siltation or the routing of pipeline canals. In those cases where canals have a general east-west orientation, the spoil banks fringing the canal may entirely block drainage. The canal itself may be equally detrimental, as it collects drainage and reroutes it in a linear pattern, thus interrupting the lateral movement of water.

Probably the most serious deviation from the biological optimum condition is where a deep channel transects the natural levee. During rising river stage, this channel allows extreme amounts of sediment to enter a basin as its depth and the velocities of flow will permit transfer of even the coarser bed load. During falling stage, the deep channel will allow excessive de-watering of the swamp. Such channels not only result from crevassing of the river, but are also dredged to facilitate access to certain basin areas.

Water Levels in Management

Although limited in quantitative aspects, the information concerning the overflow and throughflow regime and related problems can be utilized in the determination of management requirements and possibilities. With regard to a productive overflow swamp environment, the requirements are illustrated conceptually in Figure 9-2. The principal elements are the level at which water is allowed to enter a basin from the channel, and the level at which outflow should not occur. The first level, related to the stage hydrograph of the channel, is dependent on the volume of water input required, the period over which this input is desired, and the amount of allowable sediment influx. As the influx of sediment should be kept to a minimum, while regular overflow is ensured, the inflow level should approximate that of bankfull stage or natural levee height. In Figure 9-2, this level

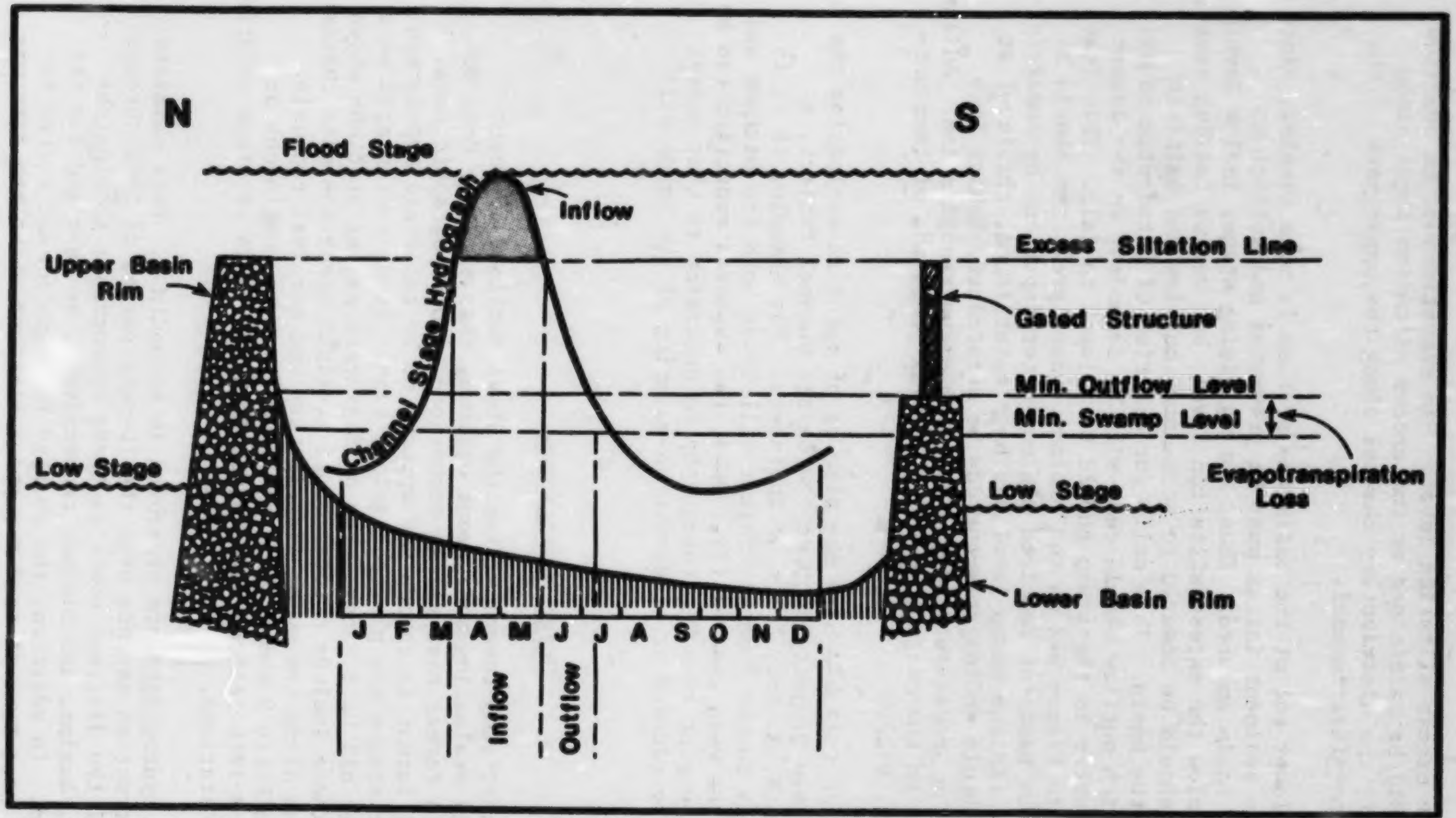
N
S
Flood Stage
Inflow
Channel Stage Hydrograph
Excess Siltation Line
Upper Basin Rim
Gated Structure
Min. Outflow Level
Min. Swamp Level
Evapotranspiration Loss
Low Stage
Low Stage
Lower Basin Rim
J F M A M J J A S O N D
Inflow
Outflow

Figure 9-2. Water level control for management of overflow swamp.

is marked as the excess siltation level. Rim elevations of an overflow swamp basin should be maintained at the excess siltation level along the main channel, the distributary channel along the upper part of the basin, and the marginal channel.

Along the lower end of the basin the problem is more complex, since at the same time sediment influx must be prevented and sufficient drainage of the basin ensured. Thus, during rising stage, inflow levels should not be below the excess siltation level, but during falling stage, rim elevations should be lowered to accommodate outflow and maintain circulation in the basin. This calls for a series of gated structures. The level at which outflow should cede will be dependent on the lowest level to which water in the swamp should be allowed to fall. This level is referred to in Figure 9-2 as the minimum swamp level, and should be determined on the basis of required minimum water depth and hypsometric data. Once the minimum swamp level has been established, the level at which outflow should no longer occur can be determined, taking into consideration the predictable water loss from evapotranspiration. Adding this water loss to the minimum water level will yield the minimum outflow level (Fig. 9-2).

The approach followed here may also be of value in evaluating the results of certain projects such as the Center Channel Project, as proposed by the U. S. Army Corps of Engineers. For example, if it is assumed that the Center Channel Project will lower both the maximum and low stages of the main channel (Fig. 9-1), the expected reduction can be analyzed with respect to basin topography to determine to what extent overflow will be reduced or excessive de-watering of the swamp will occur.

Stage Hydrographs

As the first step toward making the above outlined approach practicable and evaluating management options, channel stage data must be reduced to a format that allows comparison with topographic data. The most ideal format in common use appears to be the stage hydrograph in which river stages are plotted against time. Stage hydrographs were constructed for all U. S. Army Corps of Engineers gaging stations shown on Plate 9.* These include a total of 11 stations along the main channel and 14 stations along the major distributary and marginal channels. Information on Plate 9 shows the stage records to be continuous or partial. Incomplete records were adjusted on the basis of stage relationships between stations.

The stage hydrographs are presented in Appendix A. Data utilized in their construction extends over the 10-year period of 1961 through 1970. Each of the diagrams contains three hydrographs showing the monthly means, maxima, and minima, respectively, as averaged for the 10-year period. In addition, the average hydrographs and curves for 1961 and 1963 have been plotted for those stations where the data was available. The two years 1961 and 1963 represent a wet and a dry year, respectively, both in terms of river discharge and precipitation surplus.

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* See Appendix C

To further make the stage data amenable to analysis, stage profiles for the average annual mean, maximum, and minimum stage were plotted along the major channels. The locations of these profiles are given on Plate 10,*and the profiles are presented on Plate 11.*

Of particular interest is a comparison of the stage profiles along the main channel and the average surface elevations of the basin along the east and west side of the main channel, respectively. For comparison, these are presented in the upper part of Plate 12.* U. S. Army Corps of Engineers survey ranges are used as reference points. When inspecting the profiles, one notices that average elevations in the west and east basin are approximately equal and nearly coincide with the mean annual stage of*the river as far south as range line 9 (for location, see Plate 9). From there southward to Morgan City, average elevations are generally about 2 to 4 ft higher along the western than along the eastern basin, but in both cases, the surface profile drops below that of mean annual stage south of range line 14 (the anomalous hump in the west basin profile at range 10 is caused by the coinciding locations of this survey range and the natural levee ridge of the Atchafalaya River where its course trends west-east near the town of Atchafalaya). The extent to which mean surface elevations are below mean stage, and, even more, the difference of 2 to 10 ft between average surface elevation and flood stage, emphasize again clearly the floodbasin character of the area.

In addition to the stage profiles, Plate 12 shows the change in average river depth along the main channel. Depths decrease suddenly from 80 ft below mean sea level to less than 60 ft in the vicinity of range line 10. A second decrease in depth is found near range line 21 where channel depths become less than 30 ft below mean sea level. The first change in depth coincides with a decrease in cross-sectional area of the channel, as illustrated in the lower part of Plate 12. Both changes occur when the channel is no longer confined by artificial levees. For comparison, the proposed authorized depth and cross-sectional area for the Center Channel are added to the diagrams of Plate 12. In particular, the cross-sectional area is of interest. The deviation between the Center Channel cross-sectional area and the present bankfull area approximates the volume of material to be dredged in order to provide the proposed cross-sectional area. Calculated in this manner, the volume to be dredged would amount to 432 million yd^3.

Through interpolation, average annual mean, maximum, and minimum stages could be determined at each of the U. S. Army Corps of Engineers survey ranges where these intersect a stage profile. This allows a direct comparison of stage and topographic data by either one of two methods. The first involves the transfer of stage data to the hypsometric curves. As discussed in the previous section, this allows the translation of stage data into approximate swamp water depth. The second method involves the construction of fence diagrams showing actual topography and stages. Such diagrams were constructed for the Beau Bayou and Buffalo Cove Management Units (Plates 13),*and for the Crevasse and Upper Belle River Management Units (Plate 14). *

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* See Appendix C

The fence diagrams not only allow comparison of water levels in the channels and basin topography, but also illustrate morphologic characteristics of the individual basins. The spoil banks lining the pipeline canals and the various channels where maintenance dredging has occurred are particularly salient features in this regard. Increases in elevation of the banks as a result of spoil deposition are particularly noticeable along the main channel and Lake Fausse Point Cut on Plate 13. The effect of canal dredging on basin morphology is apparent in the irregularities of the profile surface along range line 18 (R18) on Plate 14. Individual profiles on both plates illustrate the basin concept as outlined at the beginning of this section.

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* See Appendix C

SECTION X

PROPOSED WATER MANAGEMENT PLAN FOR BUFFALO COVE AND UPPER BELLE RIVER OVERFLOW SWAMPS

There is general agreement among those familiar with the Atchafalaya Basin that the Buffalo Cove and Upper Belle River units are exceptionally productive from the wildlife and fisheries standpoint and high in scenic and aesthetic qualities. Field reconnaissance, study of remote sensing imagery, and topographic characteristics confirm these assessments. Both productivity and aesthetic qualities are related to extensive, relatively open cypress-tupelo gum swamps, interspersed with freshwater lakes and only limited de-watering during the dry season.

In recent years, these highly desirable environmental characteristics have been increasingly endangered by excessive siltation, particularly in the southern end of both units, and deterioration in circulation and water quality. For these reasons, and because of the rapid rate at which the environmental deterioration occurs, the Buffalo Cove and Upper Belle River units have been identified as high priority areas for water resource and environmental management. This management should emphasize 1) restoring or maintaining water circulation, and 2) eliminating excessive introduction of sediment.

In general, management guidelines developed through the present study are in agreement with the approach proposed by the U.S.C.E. for control of excessive siltation in the lower end of the Buffalo Cove unit. Guidelines in this regard are primarily refinements of the original proposal and an extension of the approach to the Upper Belle River unit. However, the present study has identified in particular for the Buffalo Cove unit, an additional need for improved internal drainage and circulation. Much of the deterioration in quality in this area arises from stagnant conditions in the central and upper parts of the unit. Stagnation appears to be a significantly lesser problem in the Upper Belle River unit. Deviations between discharge data for the average outflow from the basin and combined channel flow in the lower basin indicate that possibly 10 percent of the mean annual discharge moves through the Upper Belle River unit.

In regard to the Buffalo Cove unit, recommendations have been made by the New Orleans District, Corps of Engineers, for a series of small control structures in the lower end of the unit designed to prevent further siltation of the lakes. Several of the proposed structures would be of the stop log type, enabling adjustments for stage changes, and would be equipped with rollers to provide small boat access. Some small boat access improvement within the unit was also included in this plan. The U.S.C.E. plan was originally presented at a meeting of the Atchafalaya Basin Commission and subsequently discussed at a meeting of the Atchafalaya Basin Study Alternatives Task Group and a special meeting called by Mr. B.E.M. Skerrett of the Atchafalaya Basin Commission.

Proposed Plan for the Buffalo Cove Management Unit

The plan recognizes that there are four sub-basins (Fig. 10-1) within the Buffalo Cove unit. The viability of the swamps and lakes within each of these sub-basins depends upon periodic introduction of freshwater from local precipitation and overbank flooding and the gradual movement of this water through the interior drainage network of the swamps toward the south. These swamps (1, 2, 3, and 4) were identified earlier in Fig. 6-23. During dry periods of the year and low river stage, the swamps must retain a certain level of water. Thus, the fluctuating water levels create conditions that range from periodically wet to continuously submerged (Figs. 6-23 and 6-24). Throughflow is essential to maintaining high oxygen content and nutrient distribution. Excessive siltation may cause rapid and dramatic alterations in the environment. In general, siltation causes a loss of highly productive wetland habitats, and in the Buffalo Cove area, initiates an environmental succession resulting in less desirable conditions.

Elements of the proposed plan are illustrated in Figure 10-1 and include:

1) Weirs and overflow areas along the natural levee rims of Bayous Gonsoulin, Alligator, and Chene (Cross Navigation Channel), along the Atchafalaya Basin Main Channel, and along Lake Fausse Point Cut. Along the Cross Navigation Channel, spoil areas should be breached at not less than five places to provide overflow at river stages of 10 ft and above in the channel (all elevation in reference to mean sea level). The overflow areas should be as broad as possible. The largest and most important of the overflow areas should be in the vicinity of the intersection of Alligator Bayou and Range Line 15.

A minimum of four overflow weirs should be provided across the natural levee-spoil areas bordering the Atchafalaya Basin Main Channel. The northernmost of these (MC-1) should allow water to enter the maze of oil field canals in the Chicot Lake field. Overflow through this weir should be at stages of 10 ft or above. If it is not feasible to provide a weir at the main entrance canal to the oil field, spoil along the banks of the canals should be trimmed at intervals to elevations of 10 ft.

A similar overflow access point (MC-2) should be provided through the southernmost canal network of the Chicot Lake field. Overflow through this system should occur at river stages of 9-1/2 ft and above.

A third weir (MC-3) or overflow access area should be located at the canal leading into the isolated portion of Grand Lake. Overflow should enter the unit here at stages of 9 ft and above.

The fourth weir (MC-4) should be located at the Texaco Pipeline canal. Overflow at this point should occur at stages of 8 ft and above.

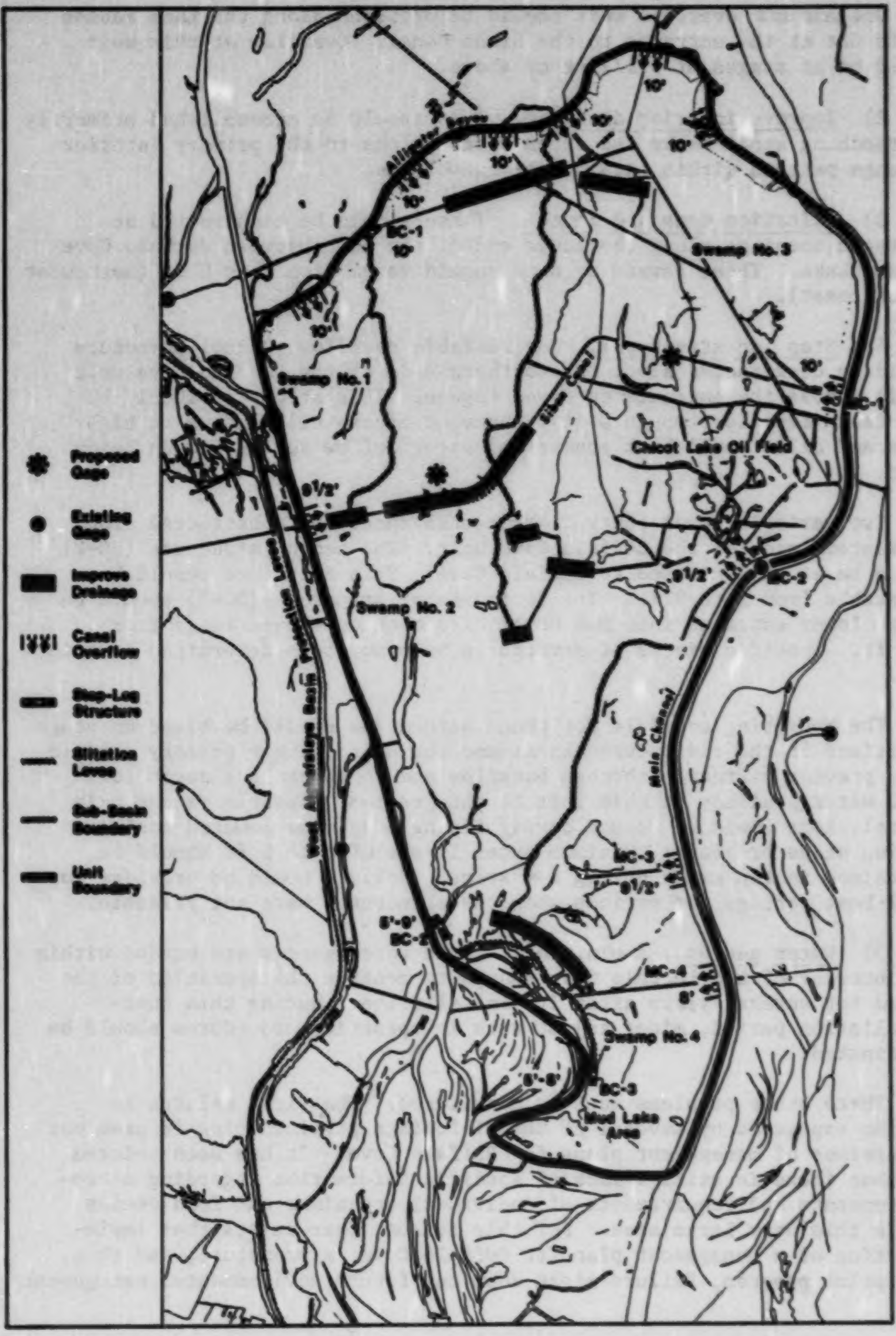

Proposed Gage
Existing Gage
Improve Drainage
Canal Overflow
Stop-Log Structure
Siltation Levee
Sub-Basin Boundary
Unit Boundary
Alligator Bayou
10'
BC-1
Swamp No. 3
Swamp No. 1
Chicot Lake Oil Field
MC-1
9 1/2'
Swamp No. 2
MC-2
West Atchafalaya Basin Protection Levee
Main Channel
MC-3
8'-9'
BC-2
MC-4
8'
Swamp No. 4
BC-3
Mud Lake Area

Figure 10-1. Proposed water management plan for Buffalo Cove Management Unit.

One minimum overflow weir should be provided along the Lake Fausse Pointe Cut at the entrance to the Sibon Canal. Overflow at this weir should be at stages of 9-1/2 ft or above.

2) Improve interior drainage. This should be accomplished primarily by breaching spoil banks and other obstructions to the primary interior drainage pattern within each of the sub-basins.

3) Siltation dams and levees. These should be constructed at strategic openings along the lower end of the unit between Buffalo Cove and Mud Lake. These levees or dams should range from 9 to 8 ft (northwest to southeast).

4) Stop log structures. One variable overflow control structure should be constructed along the northern side of the Buffalo Cove unit (BC-1) across the entrance to Bayou Eugene. This structure should be adjustable from 10 through 0 ft to prevent excess silt influx at high stage and allow small boat access and water inflow during stages below 10 ft.

Two variable level control structures should be constructed along the western side of the Buffalo Cove unit. The second structure (BC-2) should be at the entrance to Buffalo Cove. This structure should be adjustable from 5 to 9 ft. The southernmost structure (BC-3) should be at the lower entrance into Mud Cove. Its opening should range from 5 to 8 ft. Specific widths of structures have not been determined at this time.

The operating schedule for these structures should be based on stage conditions in the river channels around the unit. Their primary purpose is to prevent siltation through backflow and to maintain a north to south water gradient in this unit to the greatest possible extent. In general, logs would be raised during rising stage and lowered during falling stage or after. Minimum water levels of 6 to 5 ft should be maintained in the swamp during low stage. Rollers would be provided for small boat portage for periods when the structures were not passable.

5) Water gauges. A minimum of three water gauges are needed within the interior of the Buffalo Cove swamps to monitor the operation of the system for several years after its installation. During this post-installation period, minor adjustments in operating procedures should be anticipated.

Three other problems must be considered. The first relates to caution expressed by several of the biologists participating in previous discussions of management plans for Buffalo Cove. It has been pointed out that there is still a lack of specific information regarding macro-environments and requirements of individual organisms and food chains within this very large area. For this reason, fear exists that implementation of a management plan for Buffalo Cove is premature, and that, as a pilot program, failure might doom any future environmental management in the basin. This "no-action-at-this time" alternative must be weighed against such factors as the rate of siltation in the lower end of the basin.

The second factor concerns the large volume of sediment being diverted from the main channel through the Cross Navigation Channels into Lake Fausse Pointe Cut. As long as this condition exists, rapid siltation will continue in the lower Buffalo Cove area until all depressions are filled and a single channel achieves an equilibrium condition with the flow and sediment regime.

The third additional factor for consideration relates to institutional problems. Present considerations deal with surface water management for environmental maintenance and enhancement. Emphasis is placed on continued use of the area as part of the floodway, with commercial fishing, recreation, and forestry as primary land uses. The present proposals are not incompatible with mineral extraction or navigation interests. However, they may pre-empt other uses. Long term land uses and property rights of individual landowners and the state must be considered before any management plan is implemented.

Proposed Plan for the Upper Belle River Management Unit

Except along its southern margin, the Upper Belle River unit has a distinct advantage over the Buffalo Cove unit in that it is further removed from the primary source of sediment. Along its western margin it is separated from the main channel by the wetlands of the Crevasse unit and by Grand Lake. The Flat Lake unit separates it from the Cross Navigation Channel, largely following Bayou Sorrel. This condition generally has limited excess siltation, while not affecting freshwater input and throughflow to the point where stagnation becomes a problem of major proportion. As indicated by the aforementioned discharge data, a substantial amount of water appears to move through the Upper Belle River unit. Possibly, this condition is the result of an extremely well developed network of interior drainage channels.

The main threat to the productivity of the Upper Belle River Management Unit, from the standpoint of fisheries, lies in the high silt influx into the lakes that have formed along its southern margin. As a result of accretion along the main channel, these lakes have been incorporated in the overflow swamp, but are now in the process of being filled by the inflow of sediment-laden water primarily from the main channel. The management plan for the Upper Belle River unit, consequently, focuses upon remedying this undesirable process.

The proposed plan is illustrated in Figure 10-2, and includes: 1) weir and closures along the natural levee-spoil area extending from the lower part of the Crevasse Management Unit to the entrance of the Intracoastal Waterway branch from Berwick Bay. Water from the main channel should be prevented from entering the Willow Cove area at levels below 7 ft (mean sea level), which should reduce greatly the influx of

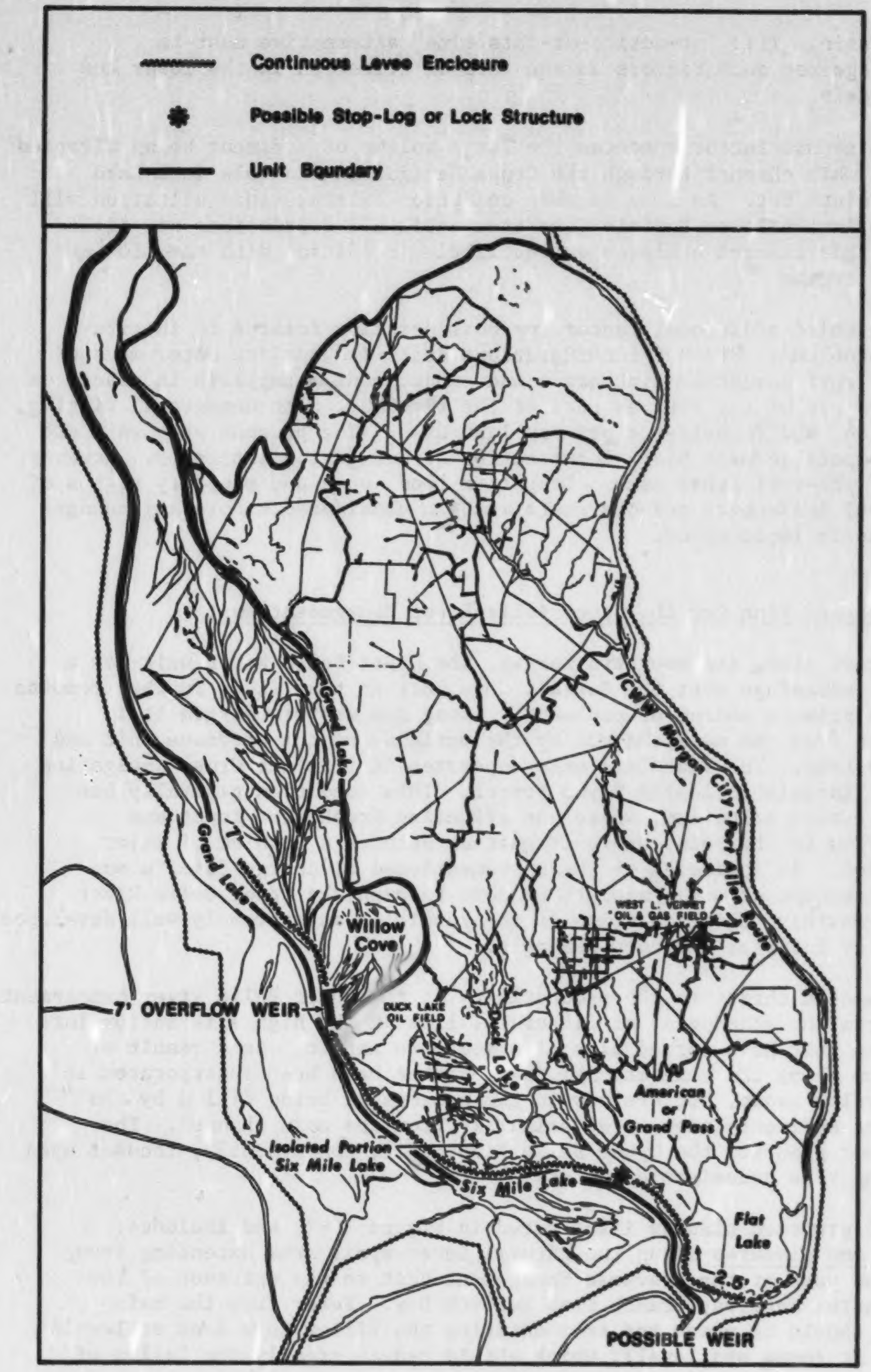

Continuous Levee Enclosure
Possible Stop-Log or Lock Structure
Unit Boundary
Grand Lake
Grand Lake
Willow Cove
7' OVERFLOW WEIR
DUCK LAKE OIL FIELD
Duck Lake
ICWW Morgan City-Port Allen Route
WEST L. VERRET OIL & GAS FIELD
American or Grand Pass
Isolated Portion Six Mile Lake
Six Mile Lake
Flat Lake
2.5'
POSSIBLE WEIR

Figure 10-2. Proposed water management plan for Upper Belle River Management Unit.

silt into Grand Lake and Duck Lake. With the exception of the major channel, all channels connecting Grand Lake-Willow Cove and the main channel should be closed by dams with crest elevations corresponding to that of the natural levee-spoil area along the main channel. At the major channel, a weir should be placed with an overflow elevation of 7 ft to maintain freshwater input during high river stages.

The natural levee-spoil area of the Upper Belle River unit along Six Mile Lake should be made continuous to prevent heavily silt-laden water to enter isolated portions of Six Mile Lake and Duck Lake. All entrance channels leading from the main channel to these lakes should be closed with the exception of American or Grand Pass, which is necessary for service of the Duck Lake oil field. If increased outflow through this channel projected for the proposed management plan appears insufficient in reducing sediment influx, the construction of a lock or stop log structure should be considered at this location. Elevation of the proposed continuous levee-spoil margin should range from 7 ft or more near Willow Cove to 2.5 ft at Berwick Bay.

2) Closure of the channel leading from the Morgan City-Port Allen route of the Intracoastal Waterway into Duck Lake.

3) Stop log structures across the channels connecting Duck Lake and the Intracoastal Waterway may be necessary if increased drainage flow through these channels proves insufficient to prevent backwater siltation into Duck Lake. In that case, minimum and maximum elevations of these structures should be -1 ft and 2.5 ft, respectively. The minimum elevation is deemed necessary to allow for small boat access.

SECTION XI

TOWARD WATER RESOURCE MANAGEMENT FOR THE ENTIRE BASIN

Studies of the Buffalo Cove and Upper Belle River units suggest that management of the overflow swamps within the floodway of the middle basin is entirely feasible. Further, the procedures outlined are believed to be compatible with the use of the basin as a floodway, which presently has priority over other land uses. An ultimate objective of the research program is to arrive at an overall plan for the entire basin that will satisfy the particular needs of each management unit, yet not reduce the discharge capacity of the floodway. Toward this end, it is necessary to examine the salient aspects of recent proposals of the Corps of Engineers to improve drainage and navigation within the middle and lower basin.

As previously discussed, the overall Atchafalaya Basin Floodway project is very complex, with many components. Those components of present concern are the so-called Center Channel and the Atchafalaya River and Bayous Chene, Boeuf, and Black Navigation Project. The former proposal calls for increasing the cross-sectional area of the main channel in the lower middle basin and confining the channel between spoil levees. This will be achieved by dredging the channel to 100,000 ft^2 cross-sectional area from mile 54.5 to about mile 105.0. From mile 105 to 112.3 (just above Morgan City), the channel would be dredged to 80,000 ft^2. It is also anticipated that a connecting channel across Six Mile Lake to the head of Wax Lake Outlet may be required at a later date. The resulting spoil would be deposited within retention dikes along the banks of the channels to form confining levees. Thus, the Wax Lake Outlet would continue to function as a distributary of the river, but presumably, most of the flow would pass through the Lower Atchafalaya Channel past Morgan City and into Atchafalaya Bay.

The working concept is that this enlarged channel will accommodate the normal regime of the Atchafalaya and by being confined, will significantly reduce siltation in the lower middle basin. It is also believed that the increased cross-sectional area will more efficiently accommodate larger discharges on those occasions when the floodway is in use.

An intimate part of the plan is closure of most distributaries including the Butte LaRose Cutoff, Bayou LaRompe, and Lake Chicot. However, some provision is being made to supply freshwater into the overflow swamps by development of East and West Freshwater Distribution Channels and East and West Access Channels, each of which connects the trunk channel with channels parallel and adjacent to the guide levees.

No provisions are outlined in the Corps plan for major dredging in either Wax Lake or the Lower Atchafalaya, where they pass through the Teche Ridge. South of the ridge, however, channel enlargement has been proposed in reference to the Atchafalaya River and Bayous Chene, Boeuf, and Black Navigation Project. This navigation project calls for enlargement of the existing channel through Atchafalaya Bay and out into the Gulf of Mexico beyond the Point au Fer Reef to 20 ft by 400 ft. The channel would extend approximately 13 mi into the Gulf beyond the reef to the 20 ft MLG contour. Through the bay area, spoil would be disposed of on the western side of the channel. This channel would be maintained above the bay in the Lower Atchafalaya River up to mile 5, where it would turn abruptly to the southeast, and after clearing the guide levees east of the channel, it would follow the Avoca Island Cutoff (bayou drainage canal) into Bayou Chene. It would branch into two "tributary channels" at its intersection with the GIWW, one branch following Bayou Boeuf, the other Bayou Black. From the navigation standpoint, this project would improve access to the port area of rig fabrication yards and other service facilities located in the backwater area east of Morgan City. From the standpoint of hydrology and water chemistry, it would significantly increase water exchange between the bay and the marshes and lakes in the project vicinity, as well as improve drainage from the Verret-Palourde Basin. The latter effect may ultimately bring about the greatest environmental changes.

With these proposed changes, then, we have one proposed model for water resource management in the study area. As shown in Figure 11-1, the trunk channel of the Atchafalaya would be largely confined to dredged channels, branching above the Teche Ridge into two major distributaries. A loop circulation system would be created in each of the overflow swamp areas of the middle basin, with dual distributaries feeding water into the upper ends of the swamps. This overflow water, along with local runoff, would re-enter the trunk channel system at the lower ends of the swamps through small tributary channels which would presumably cross the confining levees of the trunk channel.

According to the proposals, there would be no management of the Wax Lake outflow after it entered Atchafalaya Bay. Therefore, marine delta building processes would continue in this area. Water and sediment through the Lower Atchafalaya outlet, however, would largely be directed through the navigation channel. Thus, delta building processes would be largely redirected in this area to the mouth of the navigation channel.

From the standpoint of hydrology and sedimentary processes, there may be a number of difficulties with this plan as presently proposed. One of these involves the loop circulation system through the overflow swamps of the middle basin. In addition to freshwater, a large volume of transported sediment is also routed through the freshwater diversion and cross-navigation channels, which become distributaries. As it is very difficult to maintain entrances into the trunk channels without backwater siltation, the lower reaches of these major distributaries and the channels in the lower ends of the overflow swamp areas are likely to become clogged and sluggish. This will create, in effect, sediment traps or sumps, and siltation rates are likely to be high in the Buffalo Cove and Upper Belle River areas (C and D, Fig. 11-1).

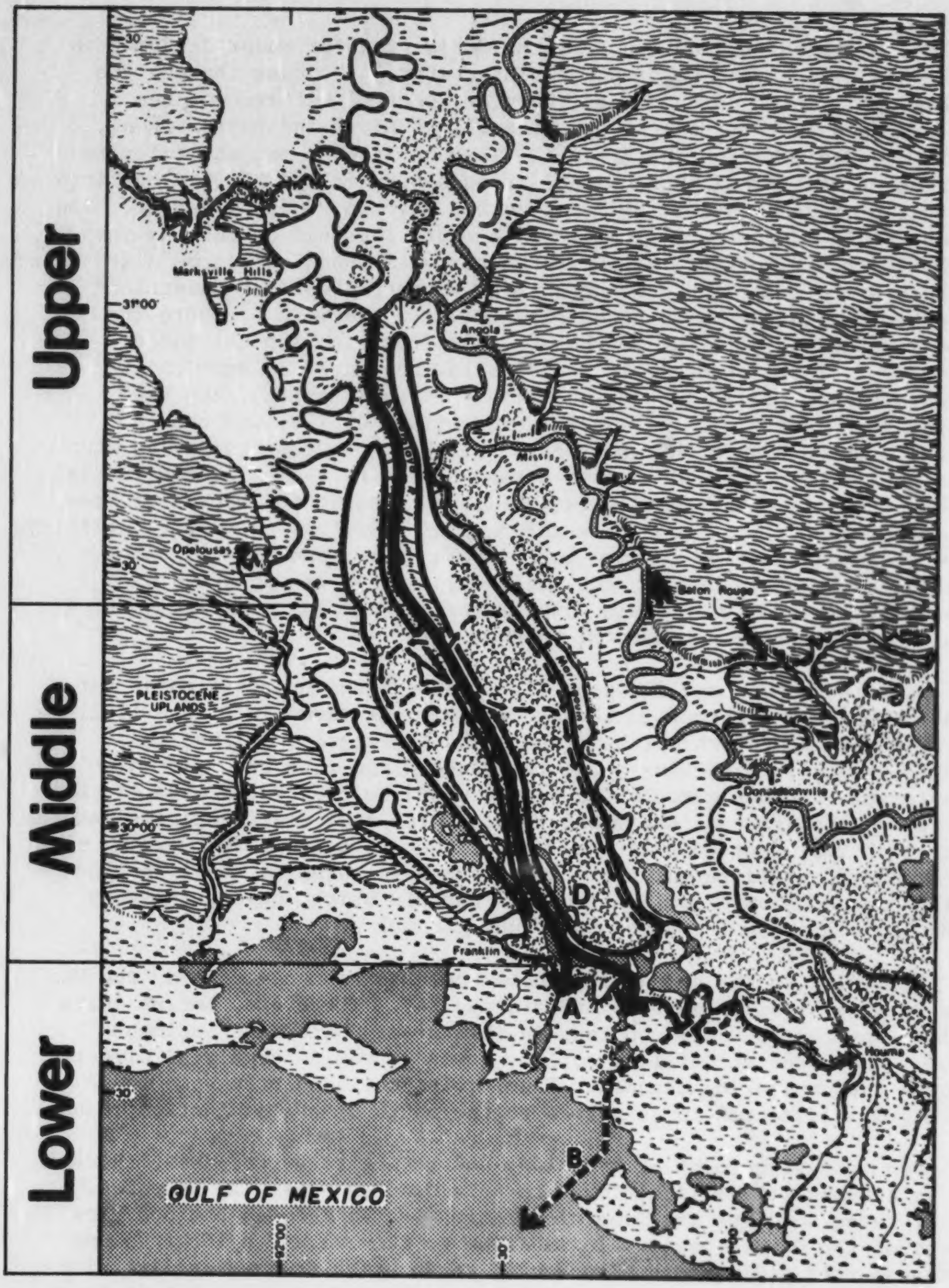

Upper
Middle
Lower
Marksville Hills
Angola
Opelousas
Baton Rouge
PLEISTOCENE UPLANDS
Donaldsonville
Franklin
Houma
GULF OF MEXICO
A
B
C
D
30'
31°00'
30'
30°00'
30'
92°00'
30'
91°00'

Figure 11-1. Salient features of existing and proposed water management projects in the Atchafalaya Basin area. A. Proposed Center Channel Project; B. Proposed Lower Atchafalaya River and Bayous Chene-Boeuf-Black Navigation Project; C. Buffalo Cove area of probable sediment trapping; D. Upper Belle River are area of probable sediment trapping.
are

Other problems of sediment control are likely to occur within the proposed navigation project, as this is presently the locus of active sediment deposition for the whole river system. The point at which the Avoca Island Cutoff enters the Lower Atchafalaya Channel will be particularly prone to siltation. By nature, tributaries never enter distributaries in delta areas. There will be a constant tendency for the mouth of the Avoca Island Cutoff to silt up.

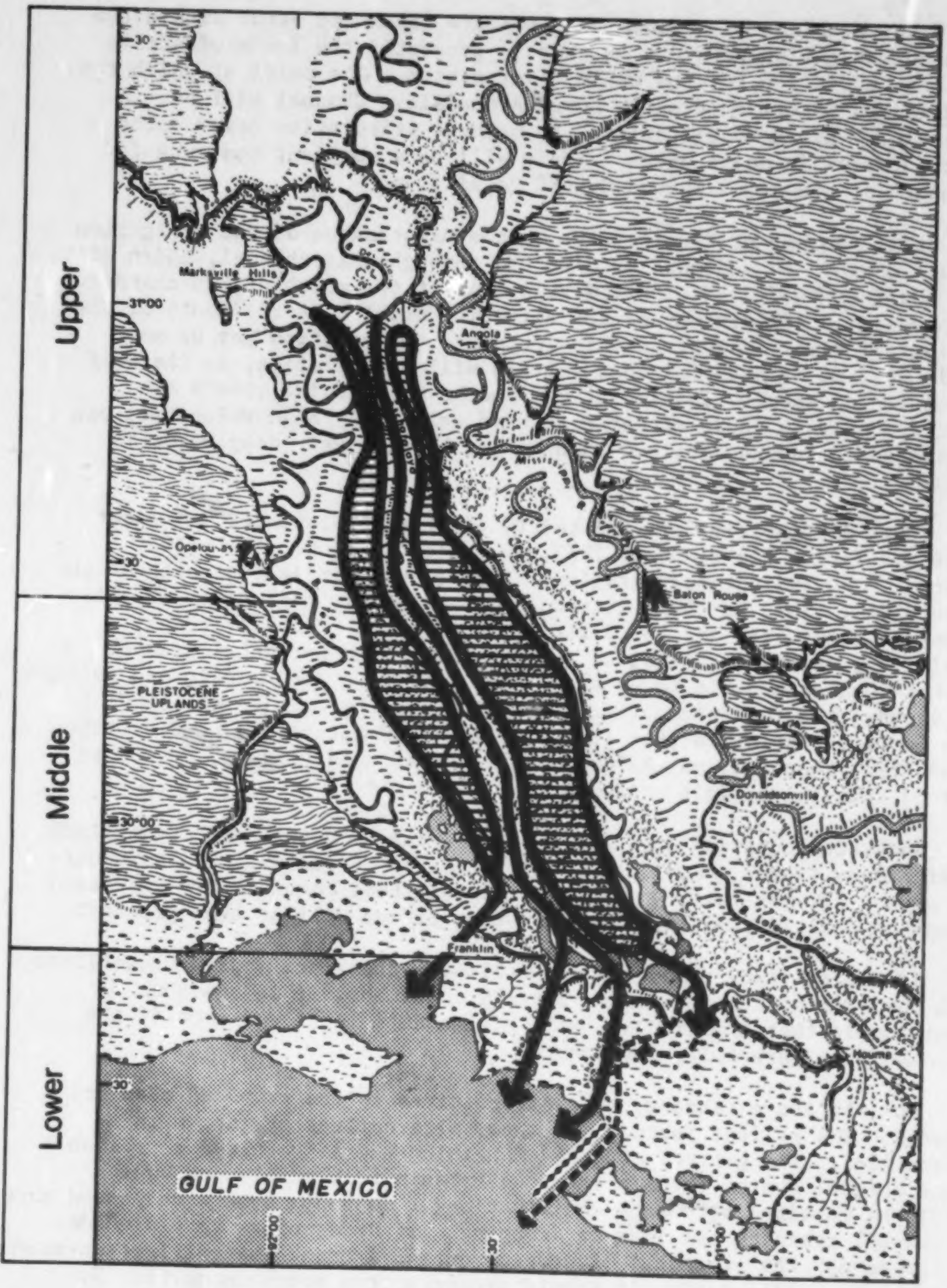
Still another problem relates to the maintenance of the navigation channel mouth. As sediment is directed through this channel, there will be a constant tendency for bar development at the mouth of the channel. The problem is reminiscent of the siltation problem at the mouth of the Mississippi River, except in this instance, the solution may be more difficult. It is doubtful that jetties will be effective, as the Gulf bottom is too shoal. Jetties at the mouths of alluvial rivers are effective only in those situations where relatively high velocities can be maintained in the confined channel until relatively deep water is reached.

Other difficulties are related to discharge capacities and water outflow. During the flood of 1973, two major difficulties became apparent. As indicated by gradient changes, water piled up north of the Teche Ridge. This has been attributed to unusually high tides in the Atchafalaya Bay area and to siltation in the bay. Probably more significant is the inability of the combined cross-sectional area of Wax Lake Outlet and the Lower Atchafalaya River to accommodate and release the floodwaters fast enough. In contrast with the opinion of the U. S. Army Corps of Engineers that the outlets served adequately to discharge flood flow, there is, on the basis of recorded water levels, reason to contend that the basin's drain is simply too small.

Backwater entering the existing Avoca Island Cutoff and Chene-Black Boeuf Bayous caused a critical flood threat to Morgan City and surrounding areas. If the cross-sectional areas of these channels are increased, it can be anticipated that this backwater effect will be even greater.

If the existing proposals are followed, there are apparent conflicts with environmental objectives. Equally important, it is somewhat questionable that the floodway will accommodate the flood even if the proposed plans are fully implemented.

For the above reasons, some alternatives to the proposed plan are offered. The salient features of these alternatives are shown in Figure 11-2. The general concept of helping the Atchafalaya establish a trunk channel system through the middle basin is a viable one, which should be retained with some modifications. Emphasis should be placed more on channel training and less on dredging. If dredging is indeed needed to "speed up" the processes of development of a trunk channel levee system through the middle basin, it should progress from south to north. By progressing from north to south, the siltation problem is aggravated. Sediment sumps may inadvertently be created. Filling of these may require


Upper
Middle
Lower
Marksville Hills
31°00'
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Angola
Opelousas
Baton Rouge
PLEISTOCENE UPLANDS
Donaldsonville
30°00'
Franklin
Houma
GULF OF MEXICO
92°00'
30'
91°00'

Figure 11-2. Alternative proposal for overall water resource management in the Atchafalaya Basin area. Hatchered areas represent overflow swamp basins. Solid arrows represent major channels. Dashed arrows are navigation channels.

future maintenance dredging, the spoil of which will more than likely remain in the middle basin.

Sediment flow into freshwater-diversion and cross-navigation canals must be controlled. Feasibility of weirs and/or navigation locks at the head of these channels should be investigated. Introduction of large volumes of sediment into the overflow swamps can only result in sedimentation and aggradation. As we have attempted to demonstrate, this has a detrimental impact on most valuable wetland environments of the system.

Re-introduction of overbank water and/or local runoff in the trunk channel through tributaries is not practical within the deltaic area of a sediment-charged river system. For this reason, to prevent backwater flooding and as a means of accommodating additional flood discharge, consideration should be given to two additional outlets for the floodway of the middle basin. One of these would parallel the Charenton Canal on the west side. This outlet would accommodate overbank water and local runoff. On the east side, a controlled outlet should be created through the east guide levee between Lake Verret and Lake Palourde. Floodwater and runoff from the basin would combine with runoff from the Palourde-Verret basin and pass north and east of Morgan City. It would pass through the Teche Ridge between Amelia and Gibson, Louisiana. Some of this flow might be directed through a revised Chene-Boeuf-Black Navigation Channel, and some would be introduced into the marshes of Terrebonne Parish, where there is a demonstrable need for supplementary freshwater.

Some maintenance dredging and/or training would increase the efficiency of the Wax Lake Outlet and the Lower Atchafalaya River channel between Six Mile Lake and Atchafalaya Bay. Delta building would be allowed to continue, but would be managed through bank training and selective dredging. However, the outfall of the Lower Atchafalaya would be directed into the bay west of the present position of the navigation channel. The navigation channel project would be revised to form a divide through the bay.

The present plan and a concept proposed in this report are shown for comparison in Figure 11-3. Our studies indicate that the concept proposed in this report would: 1) increase the discharge efficiency and capacity of the floodway; 2) reduce siltation in the middle basin; 3) supply supplementary freshwater to the marshes of western Terrebonne Parish; 4) reduce maintenance costs in navigation channels serving the Morgan City area; 5) allow for management of the emerging marine delta; 6) allow for management of the overflow swamps within the basin; 7) be compatible with existing land uses of the Basin; and 8) accommodate the drainage needs of the isolated swamp areas. Although no attempt has been made to show the structural measures necessary to implement the plan proposed in this report, preliminary study indicates that they are of the same types and orders of magnitude as those specified in present proposals.

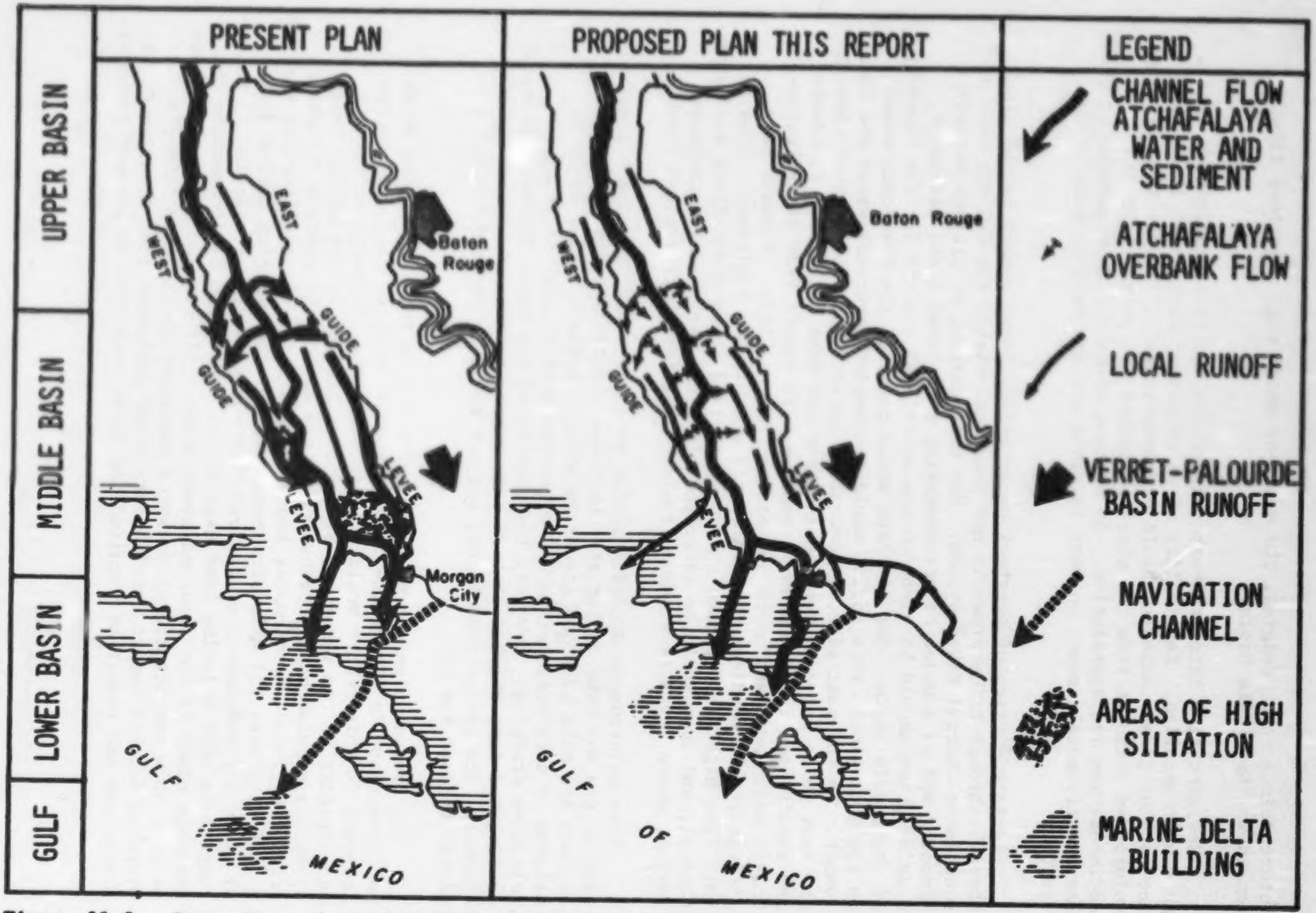
UPPER BASIN
MIDDLE BASIN
LOWER BASIN
GULF
PRESENT PLAN
PROPOSED PLAN THIS REPORT
LEGEND
WEST
EAST
GUIDE
GUIDE
LEVEE
LEVEE
Baton Rouge
Morgan City
GULF
OF
MEXICO
CHANNEL FLOW ATCHAFALAYA WATER AND SEDIMENT
ATCHAFALAYA OVERBANK FLOW
LOCAL RUNOFF
VERRET-PALOURDE BASIN RUNOFF
NAVIGATION CHANNEL
AREAS OF HIGH SILTATION
MARINE DELTA BUILDING

Figure 11-3. Comparison of present USCE proposals for water management in the Atchafalaya Basin area with those developed in this report.

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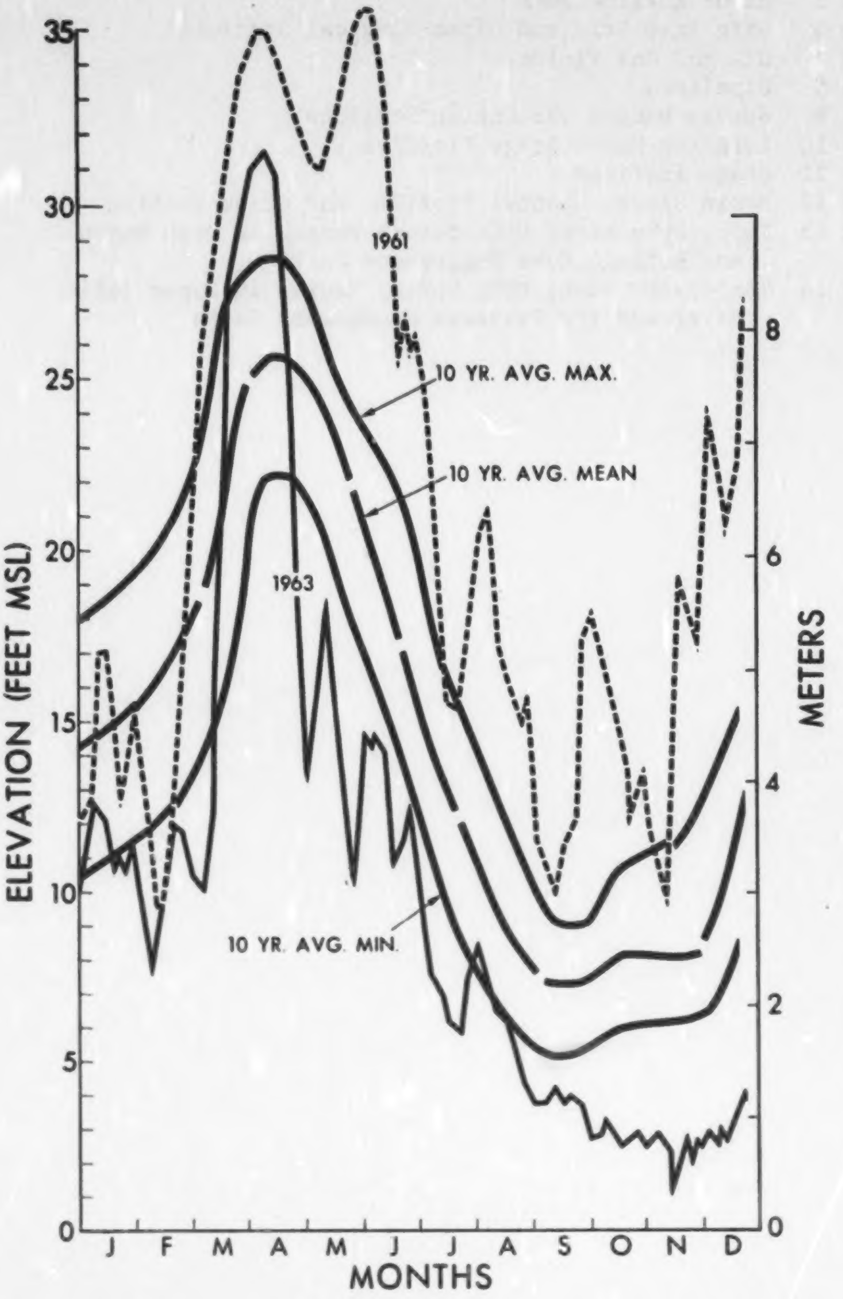

Figure A-1. Stage hydrographs at Krotz Springs, Station 4, from records of 1961 through 1970.

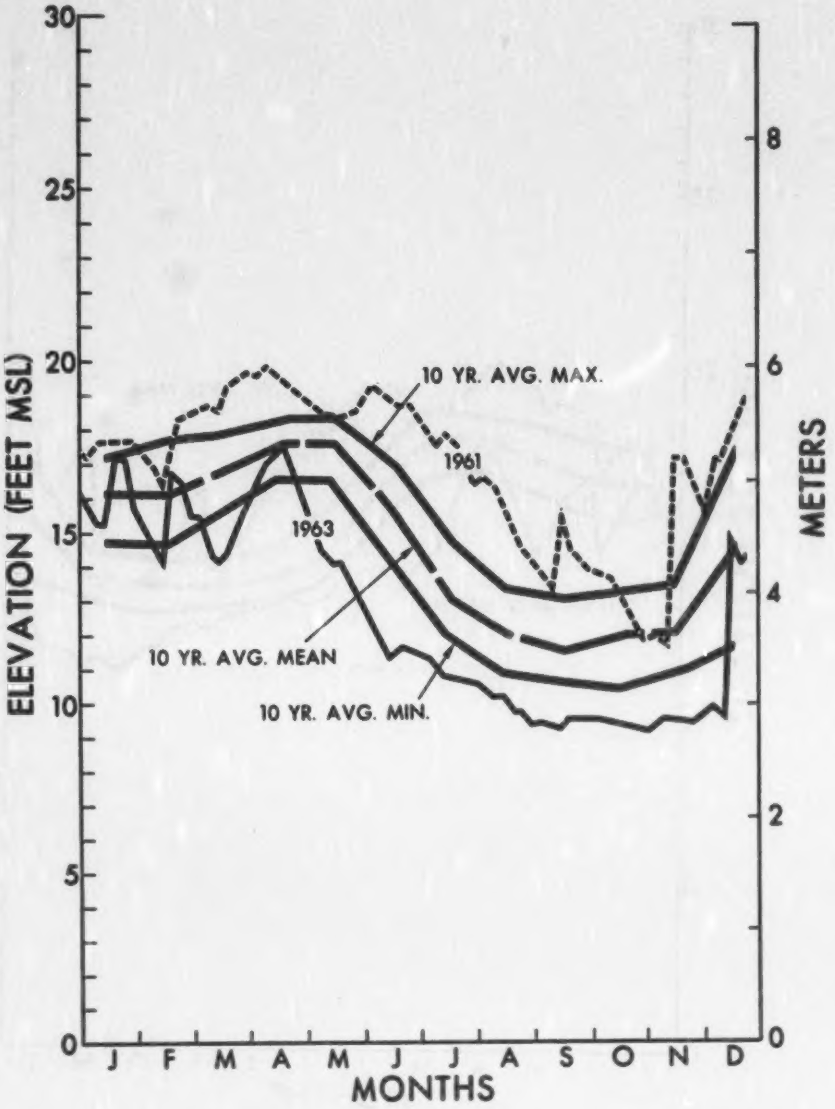

Figure A-2. Stage hydrographs at Bayou Courtableau, Station 18B, from records of 1961 through 1970.

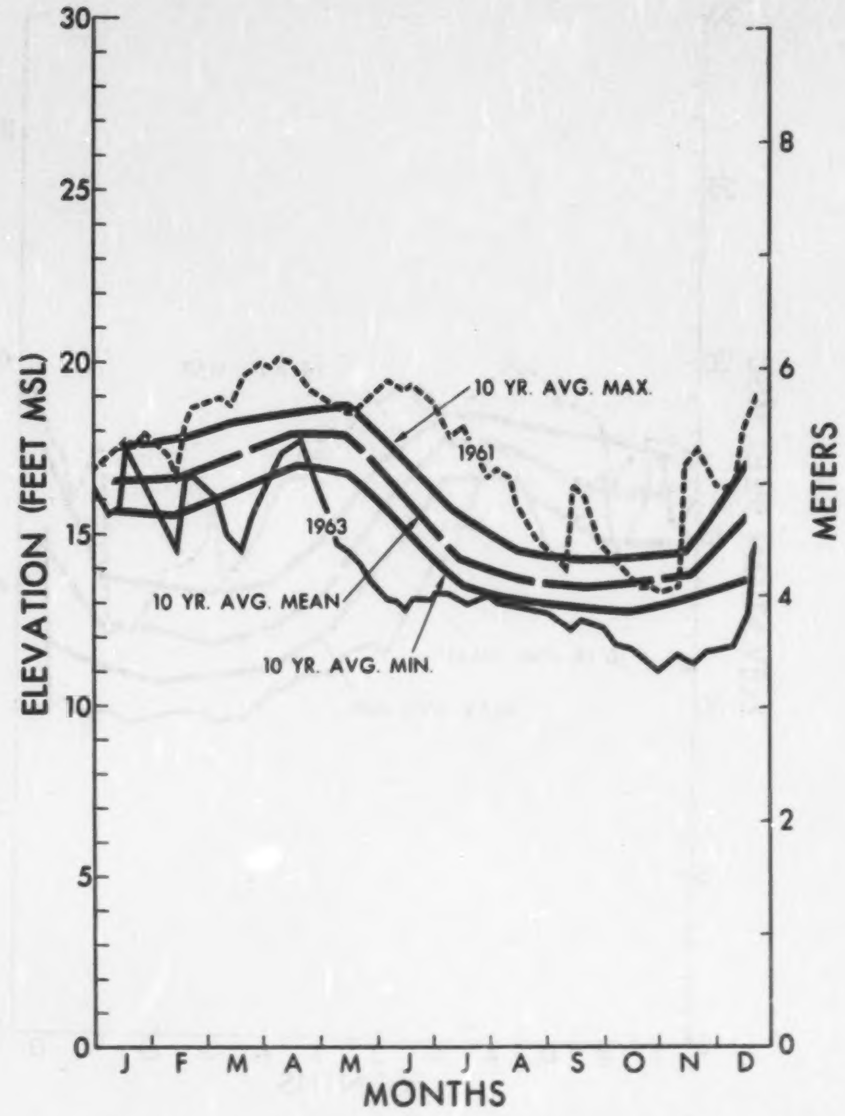

Figure A-3. Stage hydrographs at Bayou Fordoche, Station 16B, from records of 1961 through 1970.

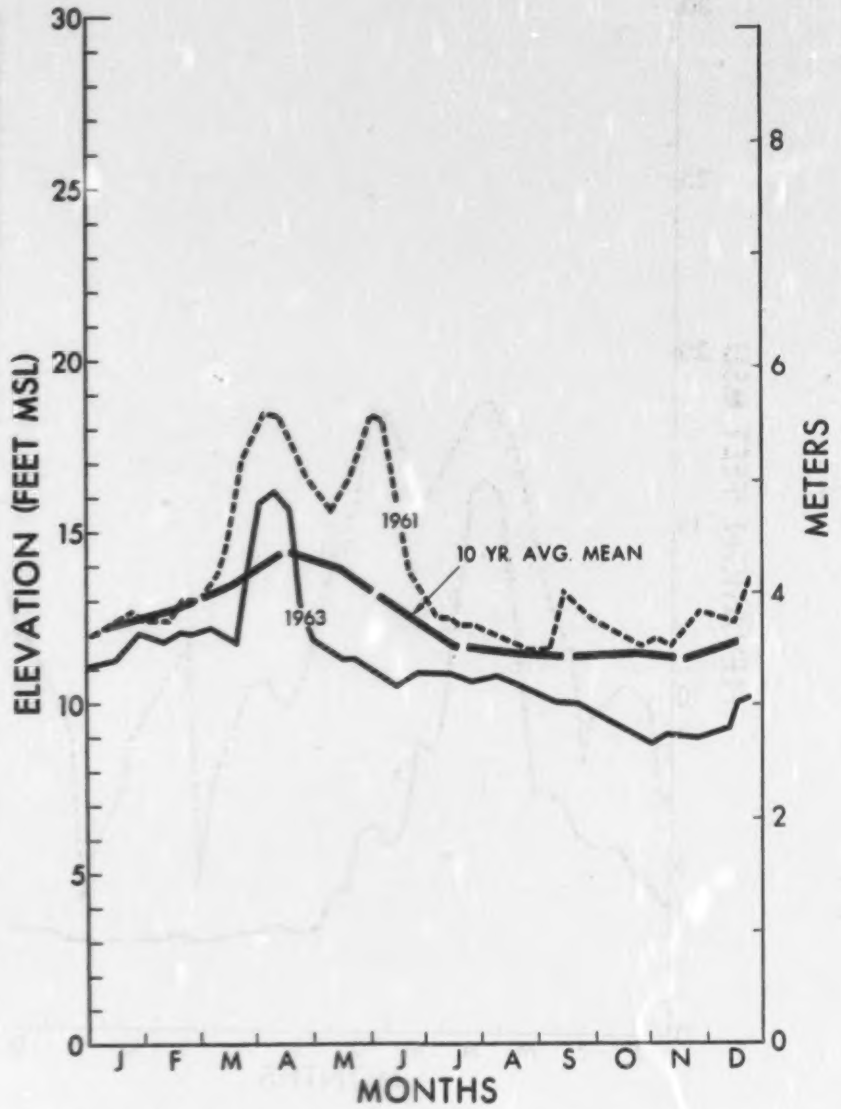

Figure A-4. Stage hydrographs at Dixie Bayou, Station 1B, from records of 1961 through 1970.

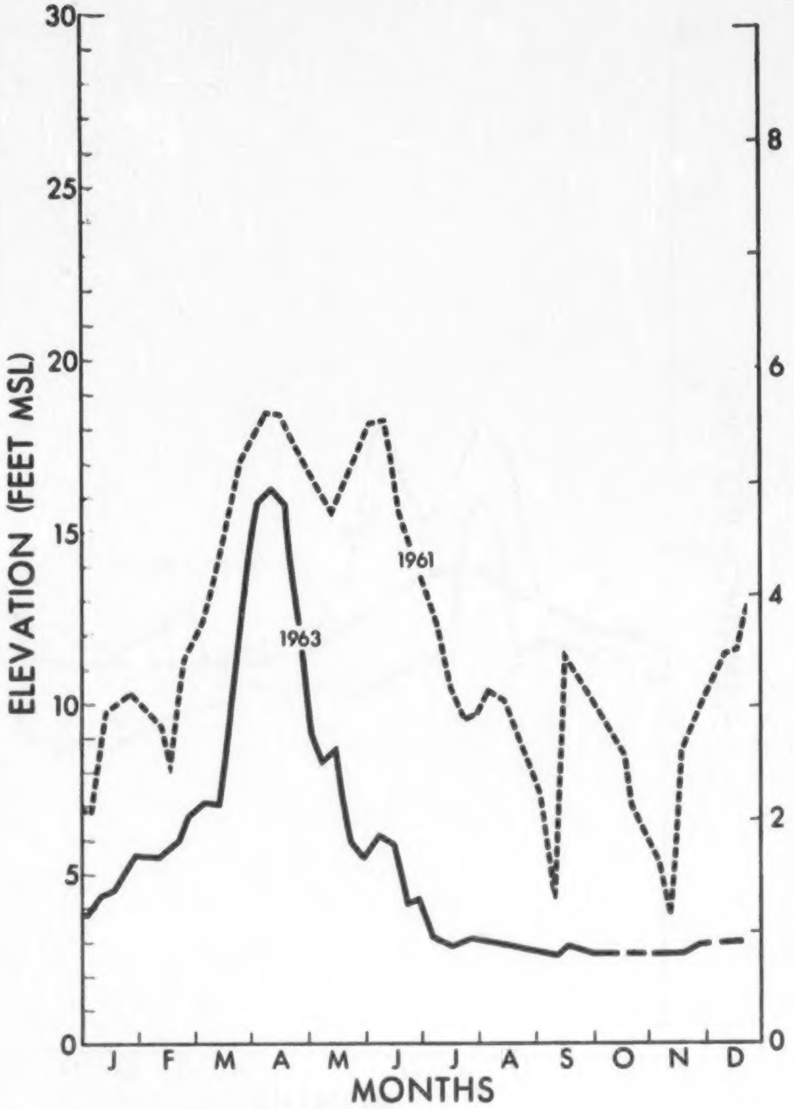

Figure A-5. Stage hydrographs at Ramah, Station 2aB, from records of 1961 through 1970.

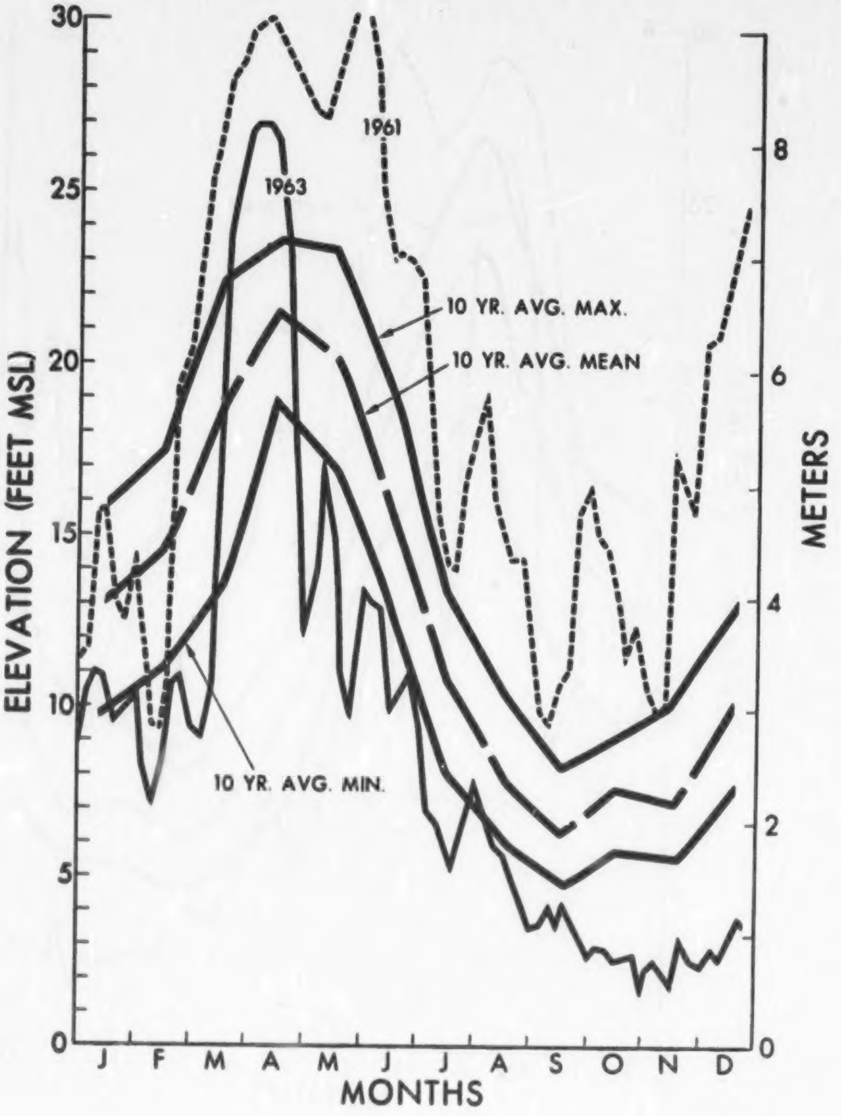

Figure A-6. Stage hydrographs at Whiskey Bay, Station 7, from records of 1961 through 1970.

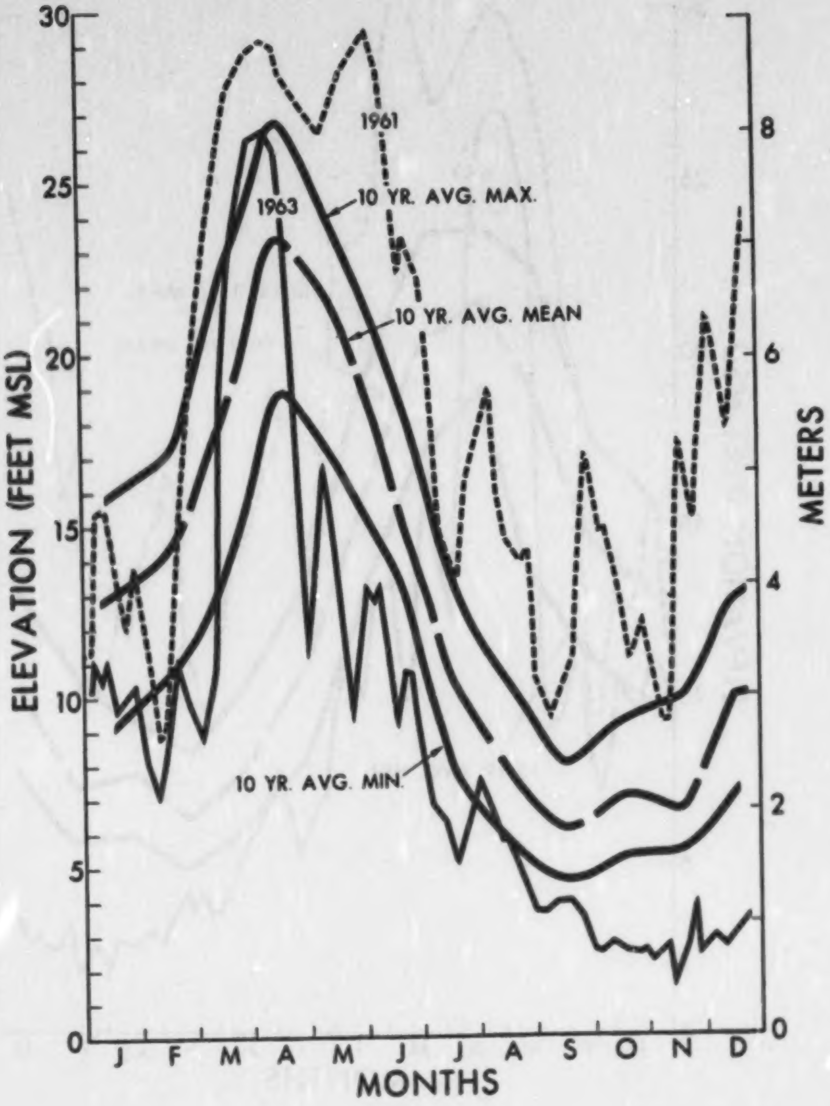

Figure A-7. Stage hydrographs at Atchafalaya, Station 5, from records of 1961 through 1970.

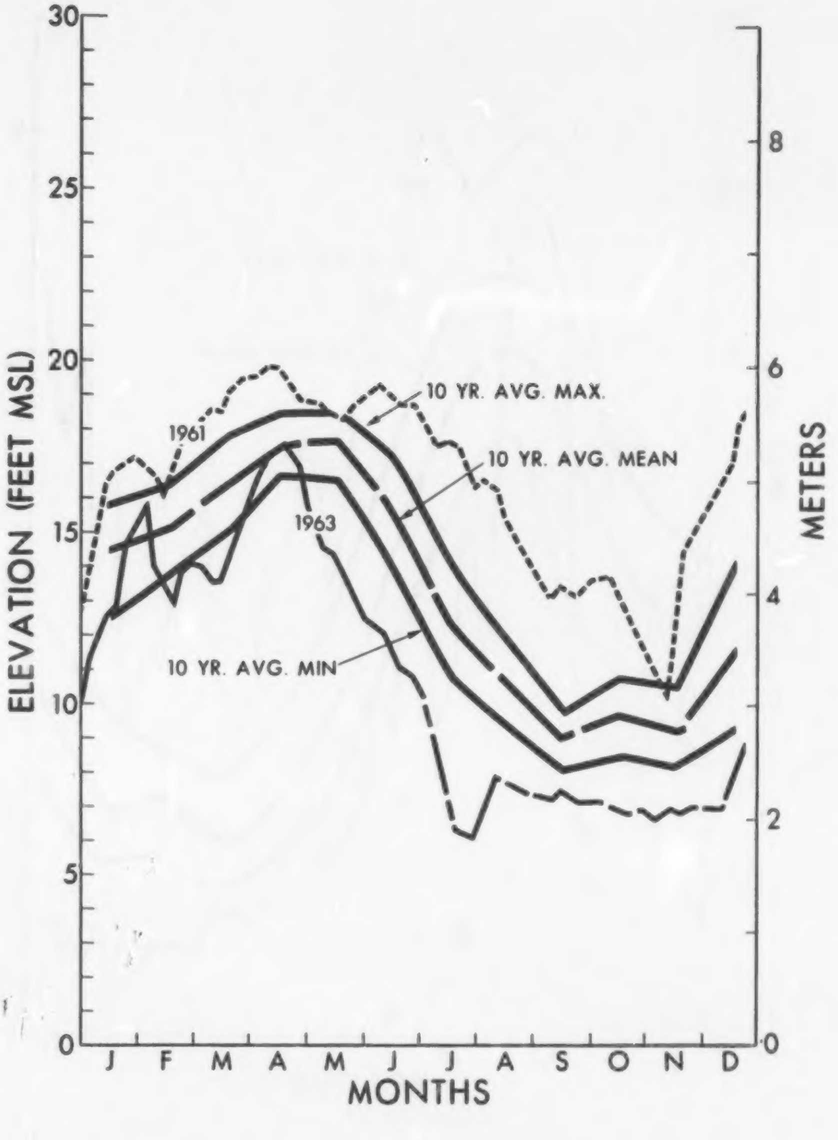

Figure A-8. Stage hydrographs at Cleon, Station 15B, from records of 1961 through 1970.

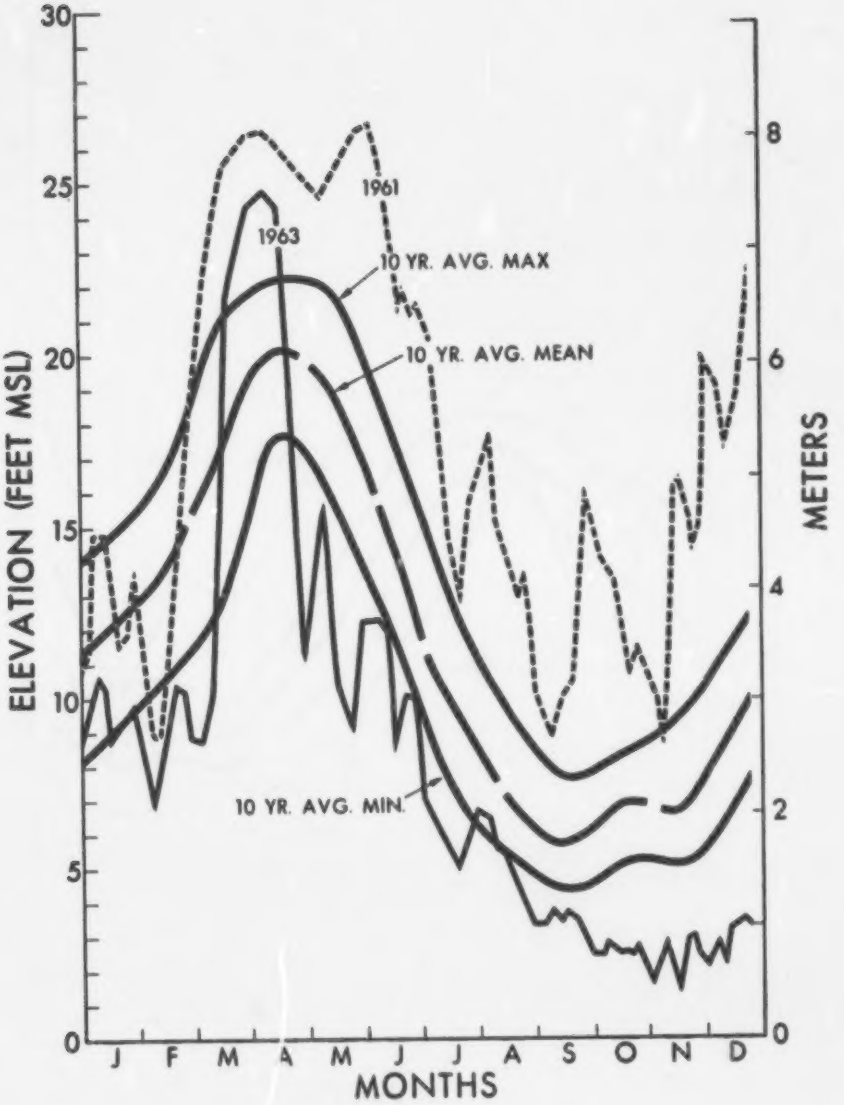

Figure A-9. Stage hydrographs at Butte La Rose, Station 6, from records 1961 through 1970.

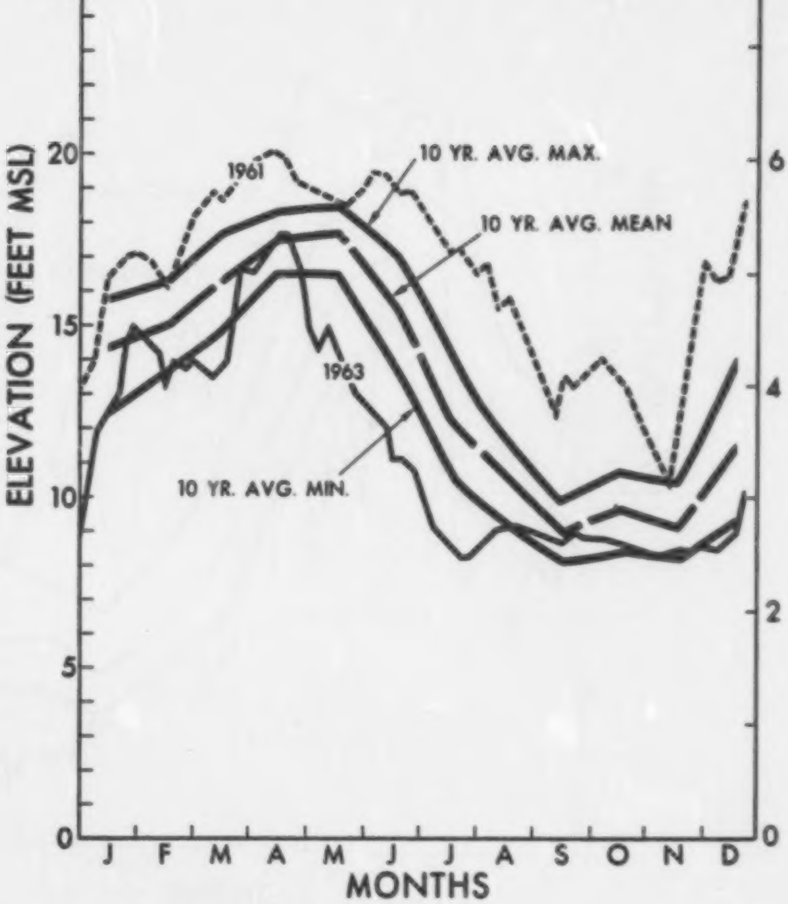

Figure A-10. Stage hydrographs at Butte La Rose, Station 13B, from records 1961 through 1970.

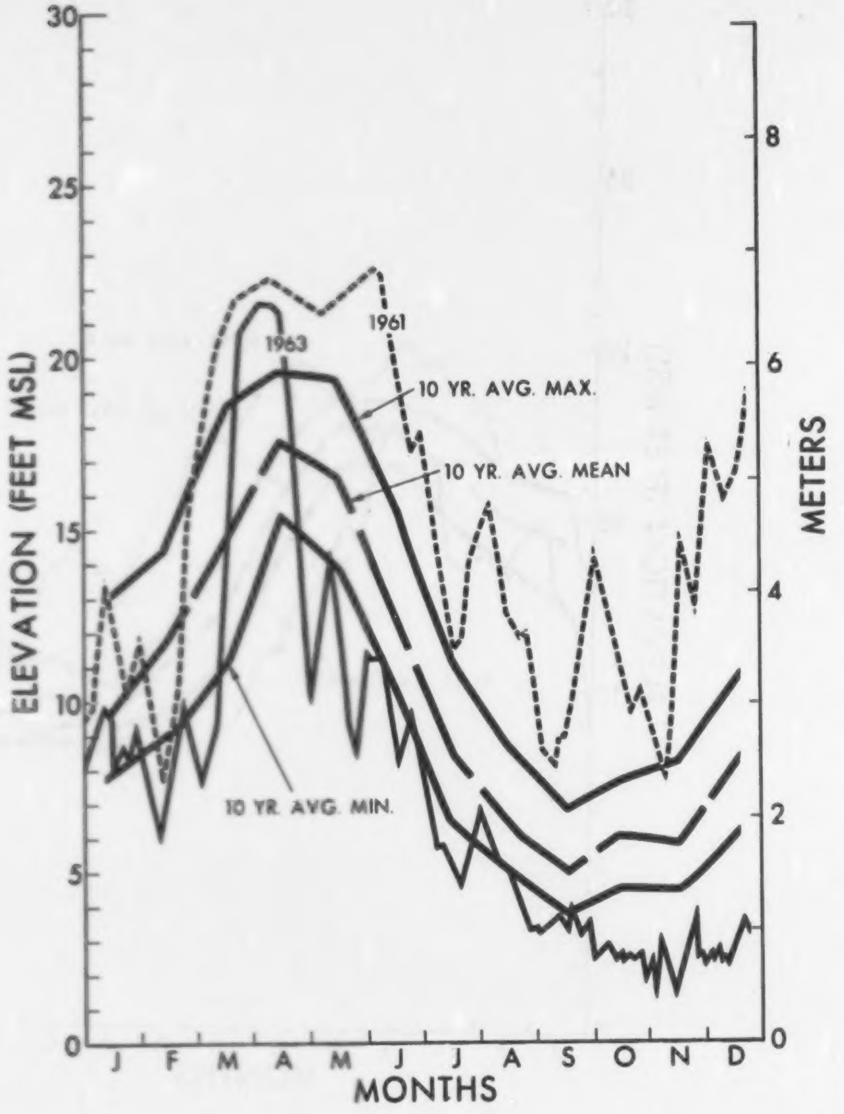

Figure A-11. Stage hydrographs at Blind Tensas Cut, Station 8, from records of 1961 through 1970.

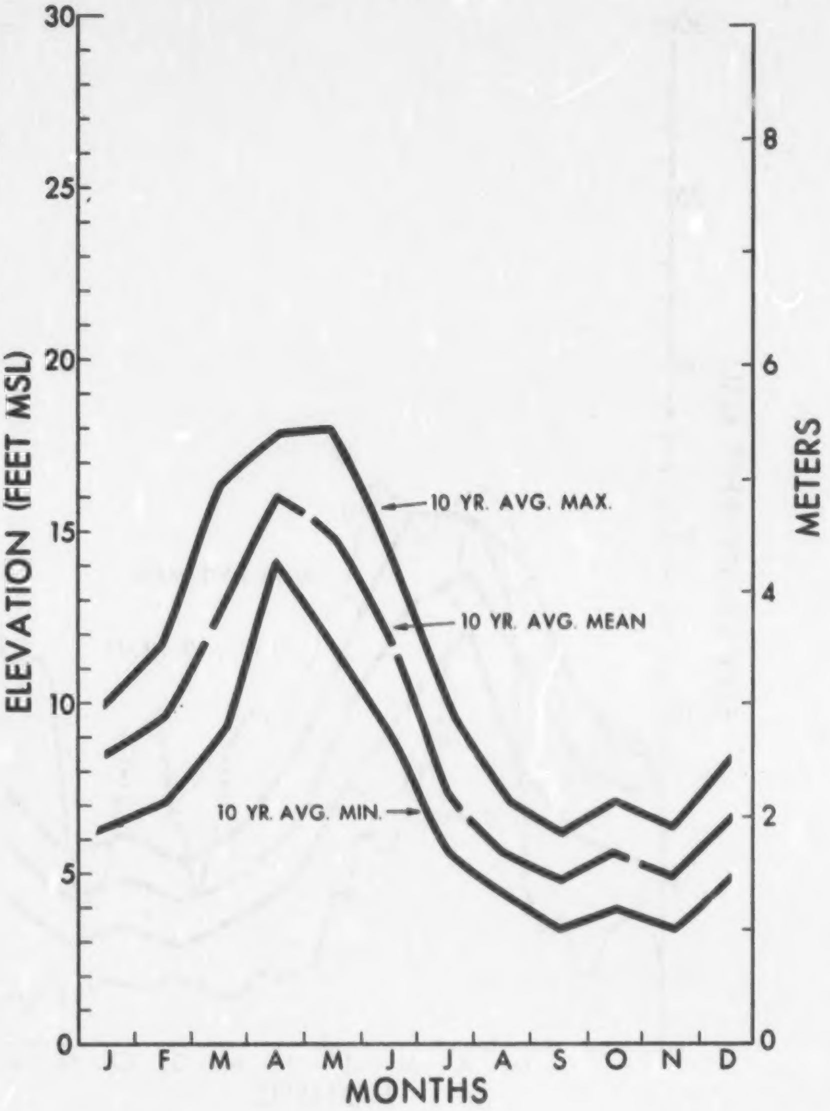

Figure A-12. Stage hydrographs at Upper Grand River at Little Tensas Bayou, Station 3B, from records of 1961 through 1970.

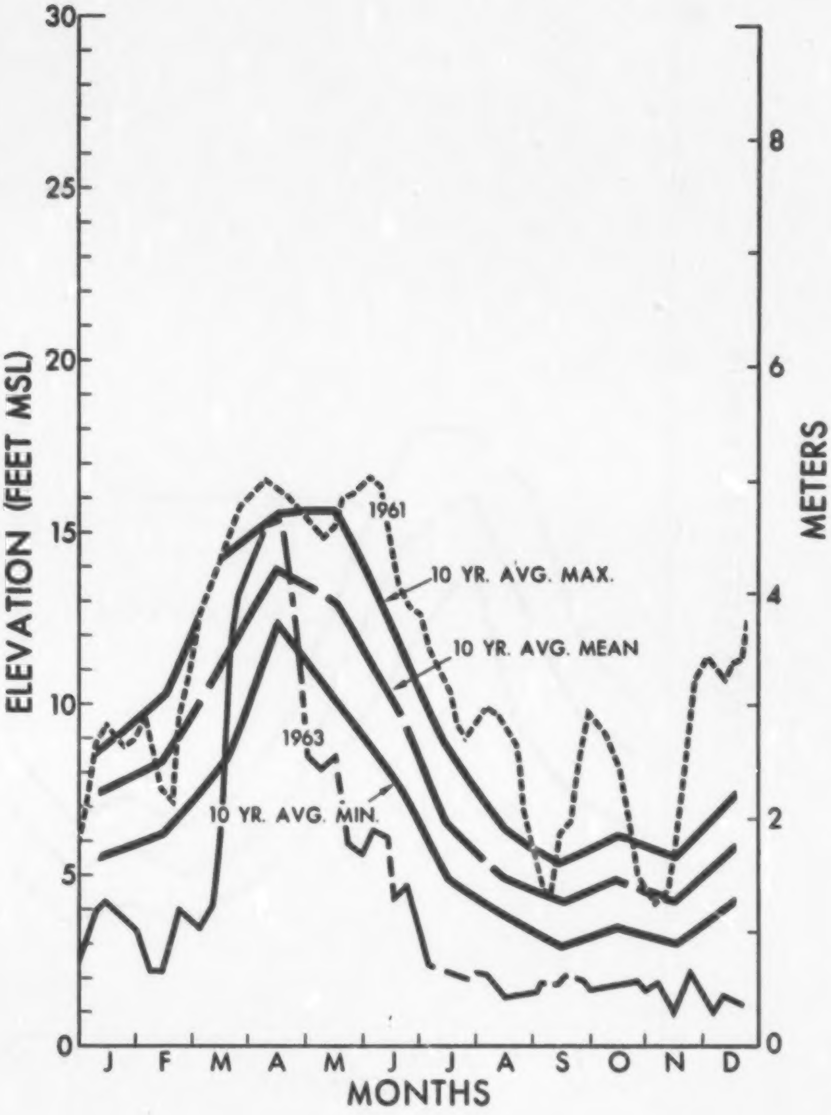

Figure A-13. Stage hydrographs at Upper Grand River at Dike, Station 4B, from records of 1961 through 1970.

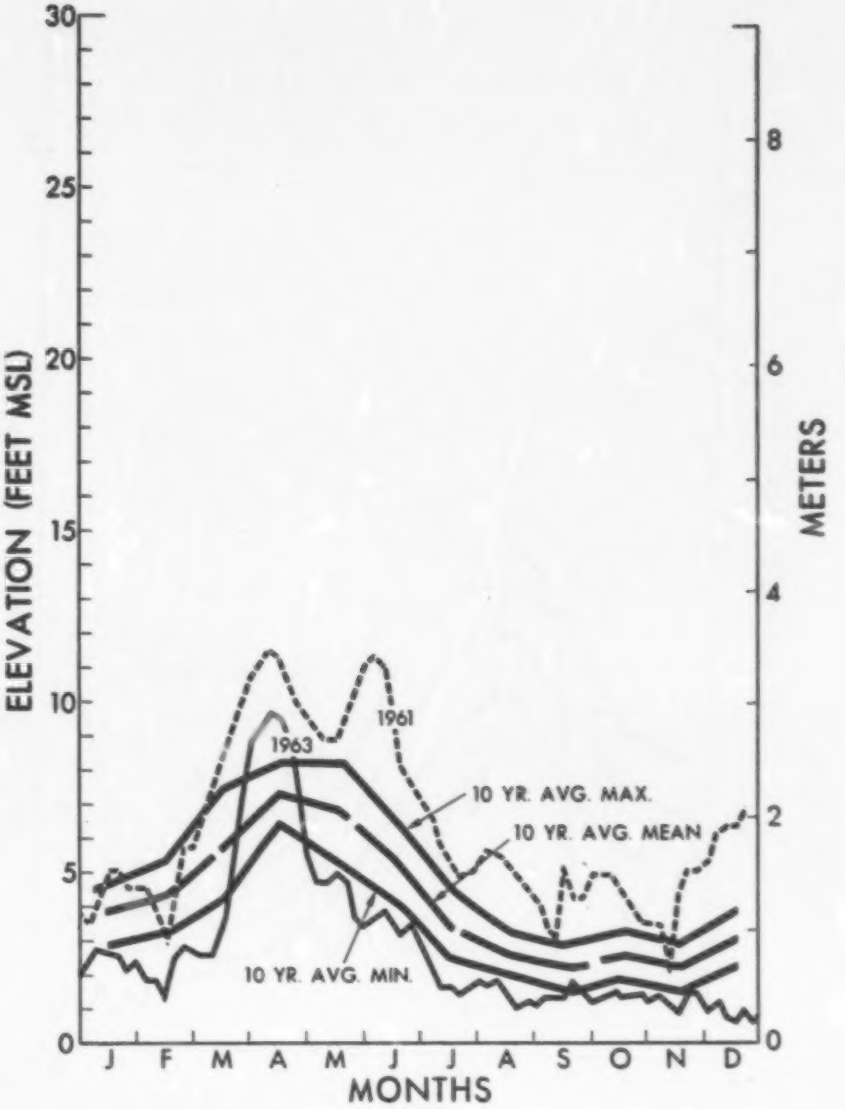

Figure A-14. Stage hydrographs at Bayou Sorrel, Station 5B, from records 1961 through 1970.

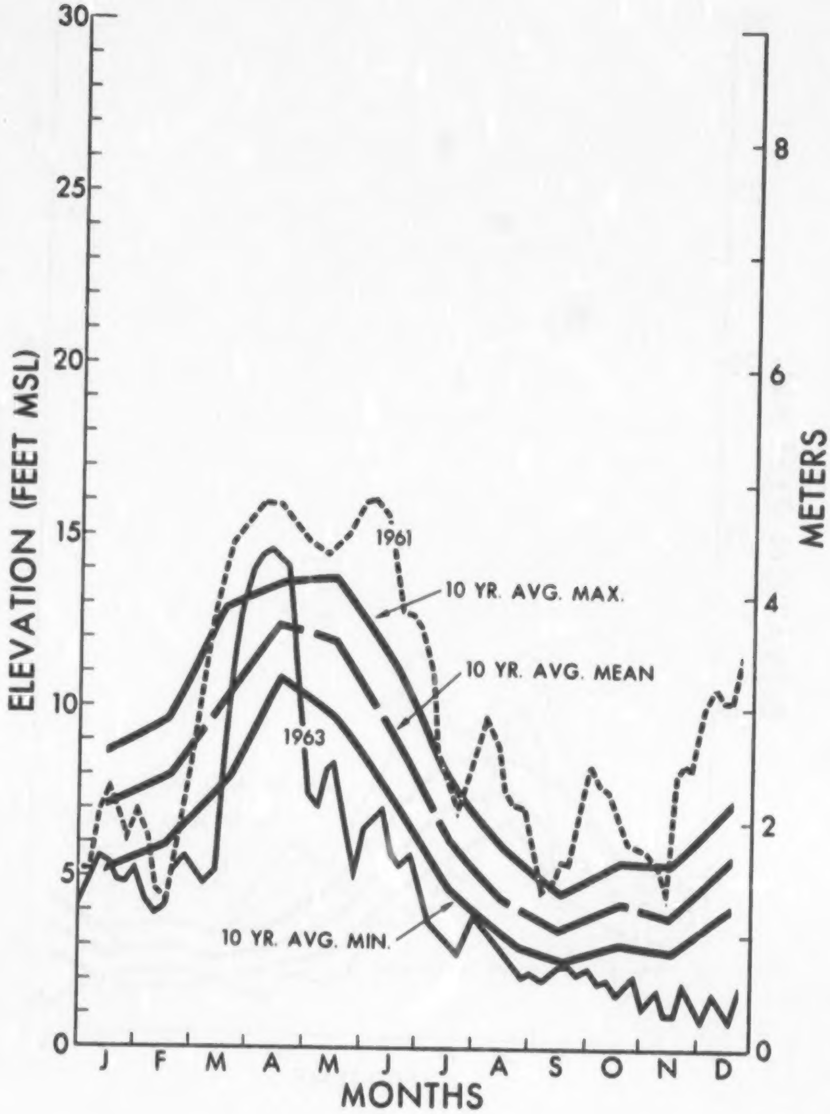

Figure A-15. Stage hydrographs at Lower Grand Bayou, Station 11B, from records 1961 through 1970.

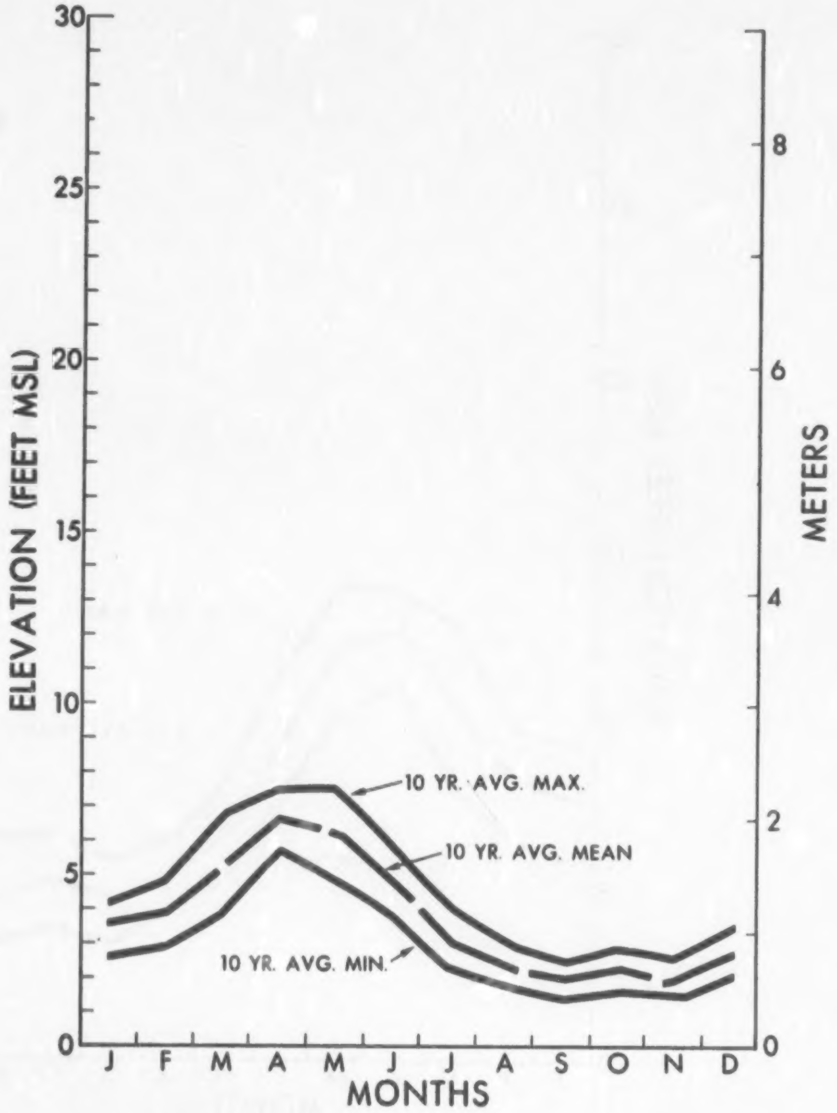

Figure A-16. Stage hydrographs at Bayou Pigeon, Station 6B, from records 1961 through 1970.

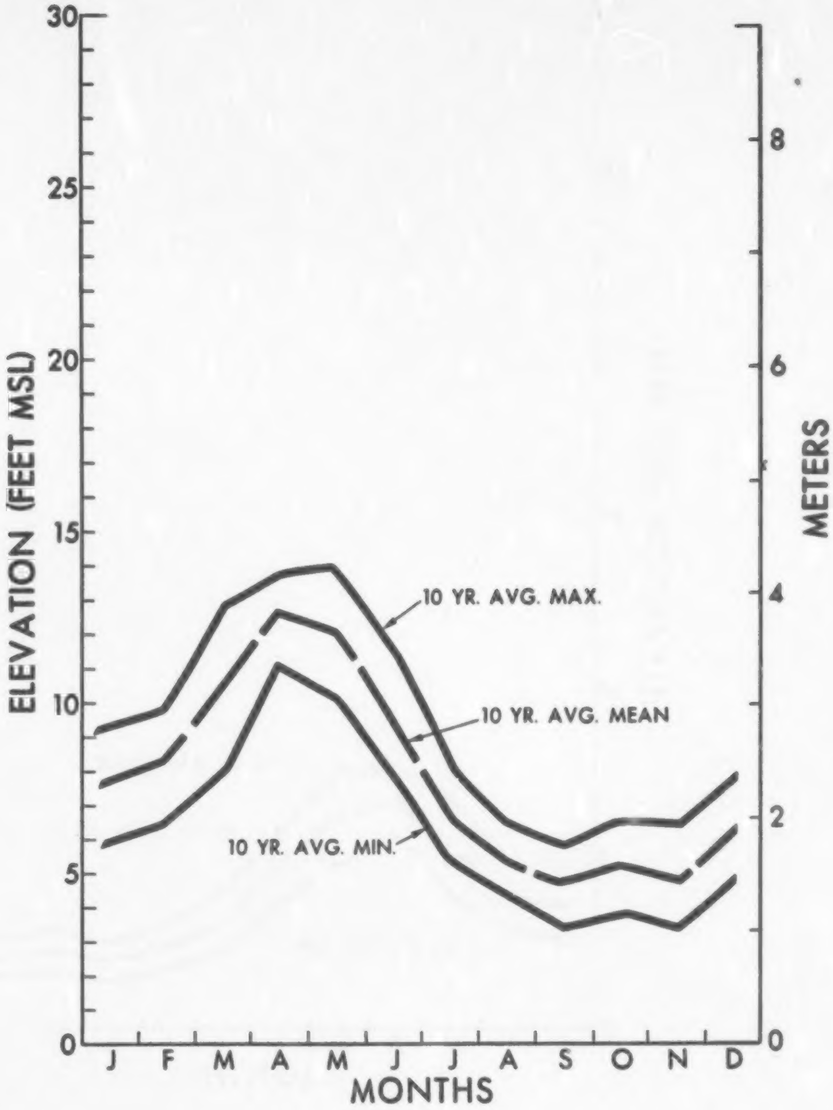

Figure A-17. Stage hydrographs at West Fork Chicot Pass, Station 9, from records 1961 through 1970.

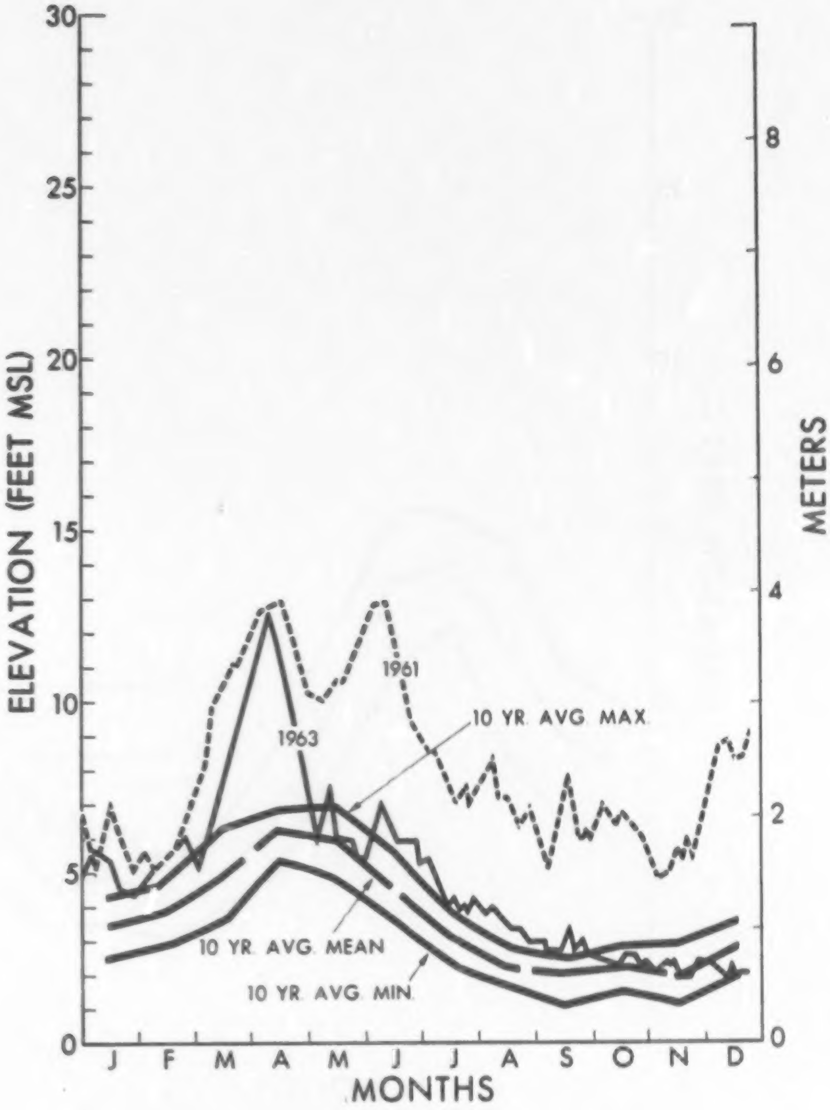

Figure A-18. Stage hydrographs at Keelboat Pass, Station 13, from records 1961 through 1970.

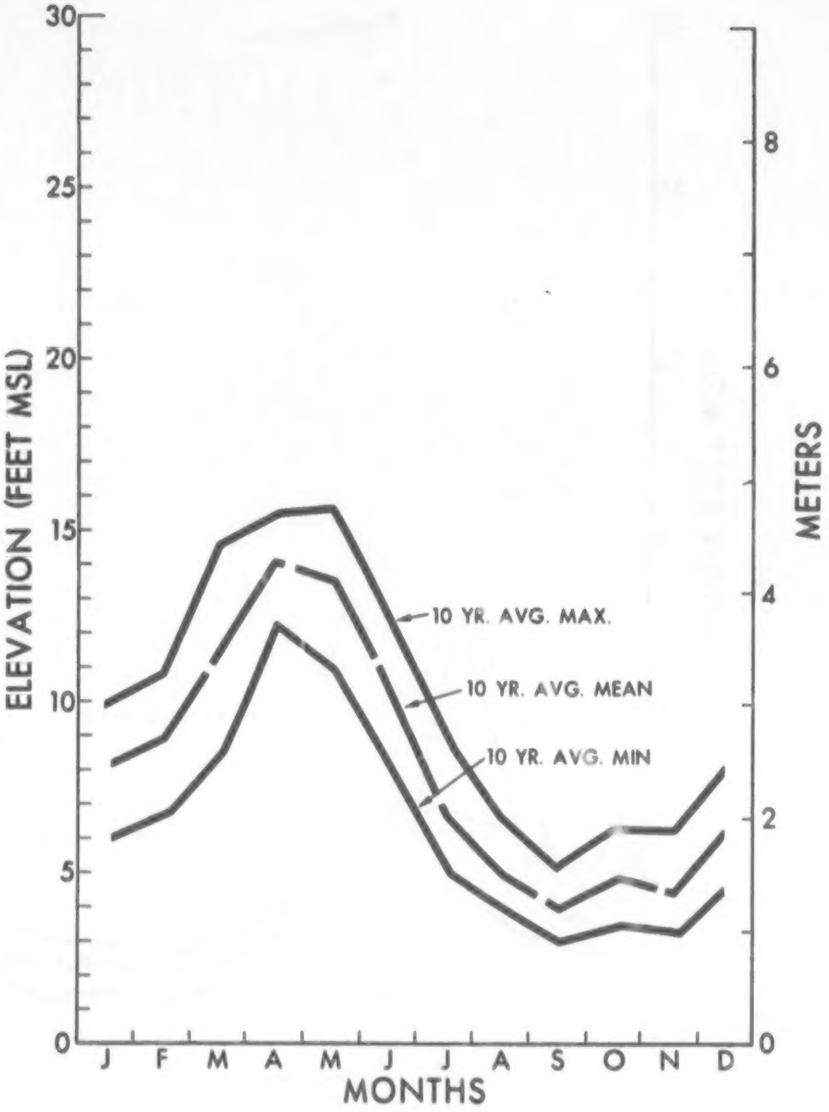

Figure A-19. Stage hydrographs at Little Lake Long, Station 10B, from records 1961 through 1970.

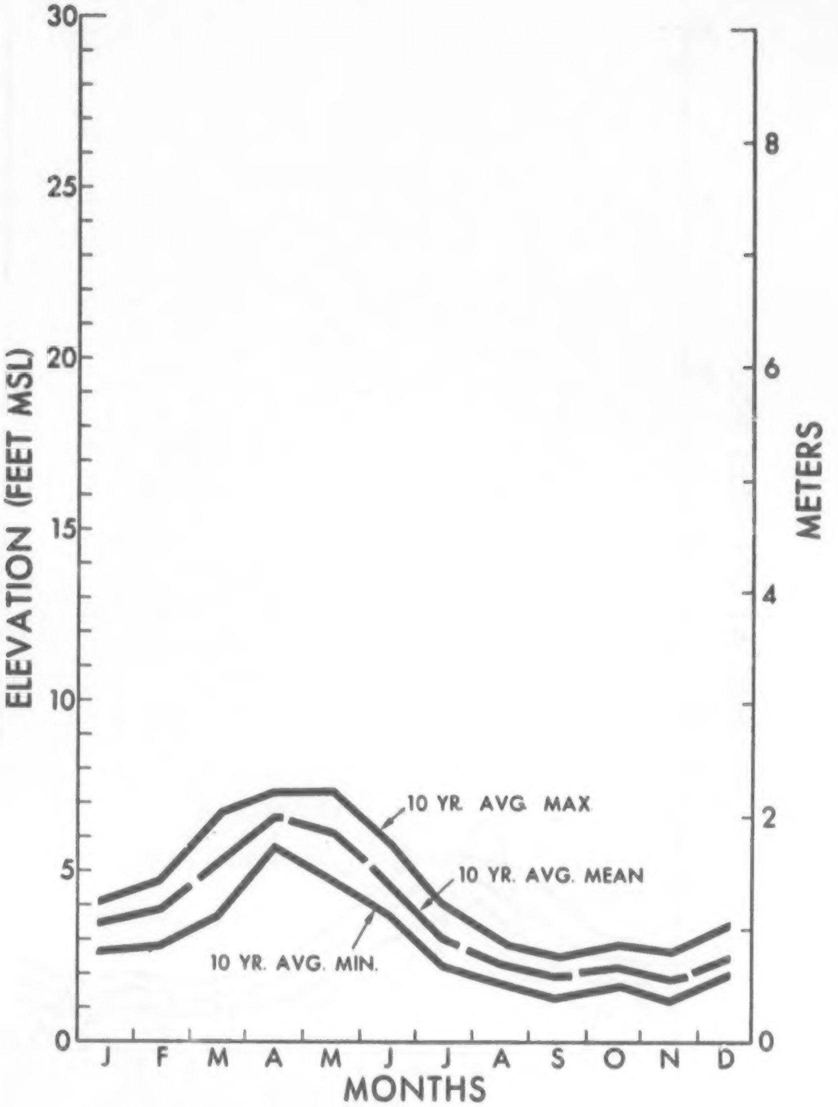

Figure A-20. Stage hydrographs at Old River at GIWW, Station 7B, from records 1961 through 1970.

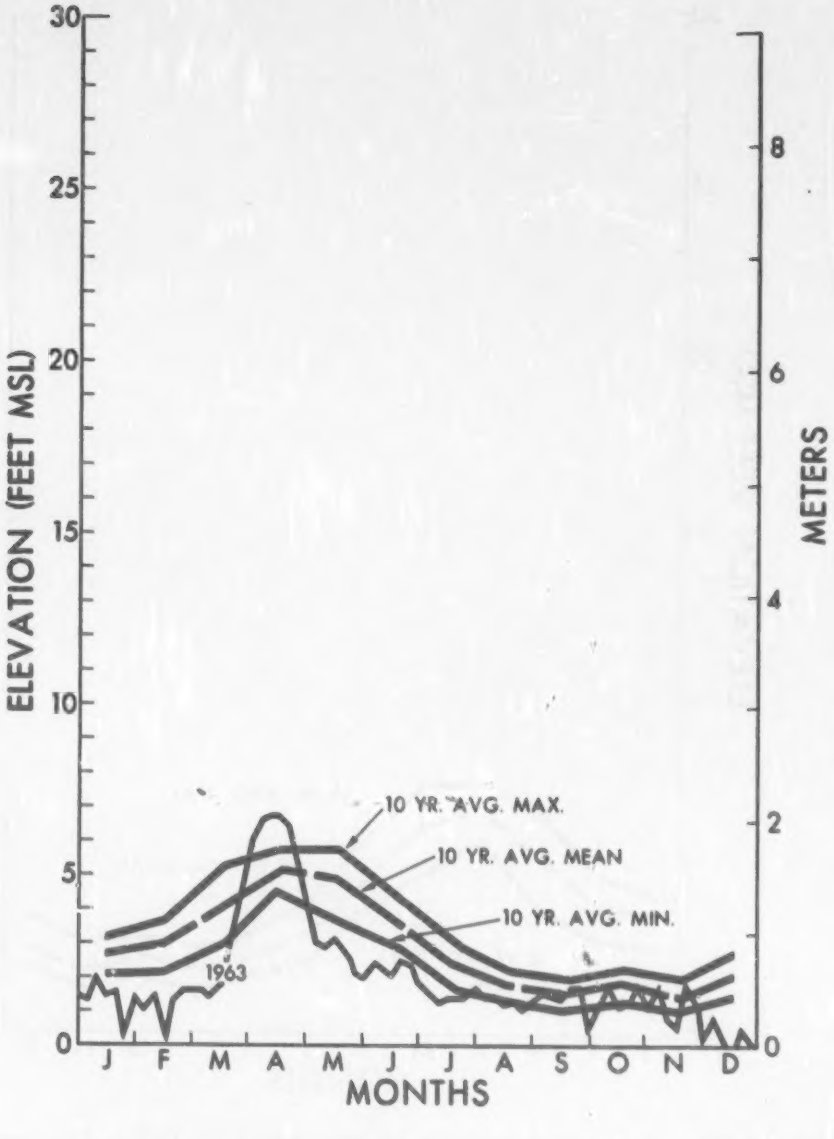

Figure A-21. Stage hydrographs at GIWW near Pierre Pass, Station 8B, from 1961 through 1970.

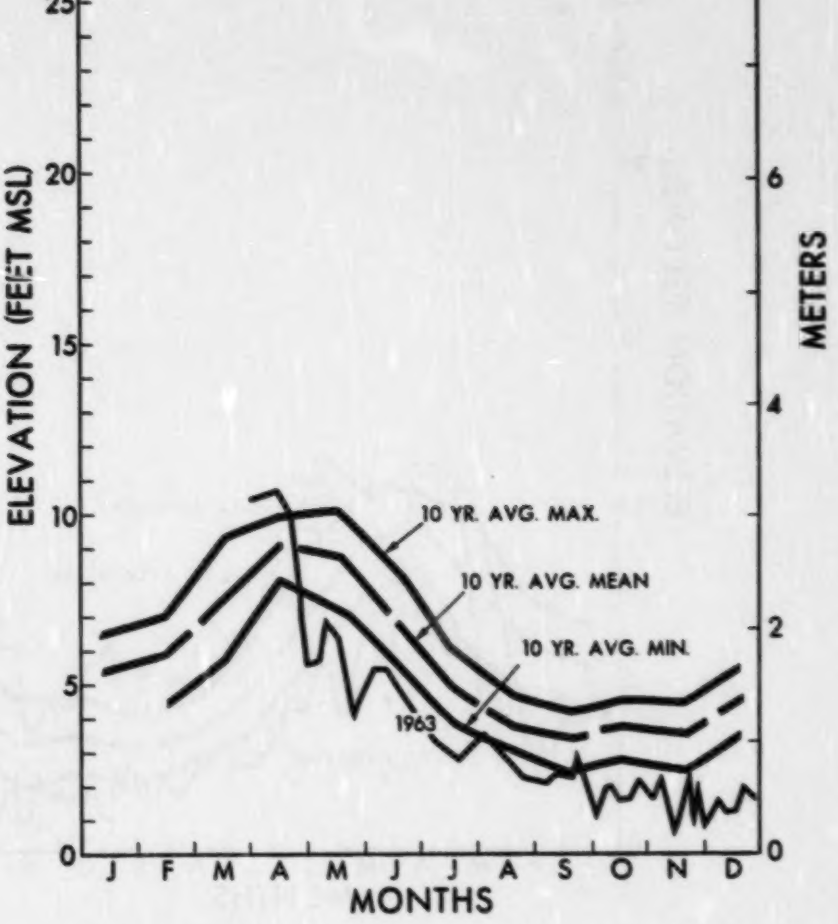

Figure A-22. Stage hydrographs at Chicot Pass at Myette Point, Station 11, from records 1961 through 1970.

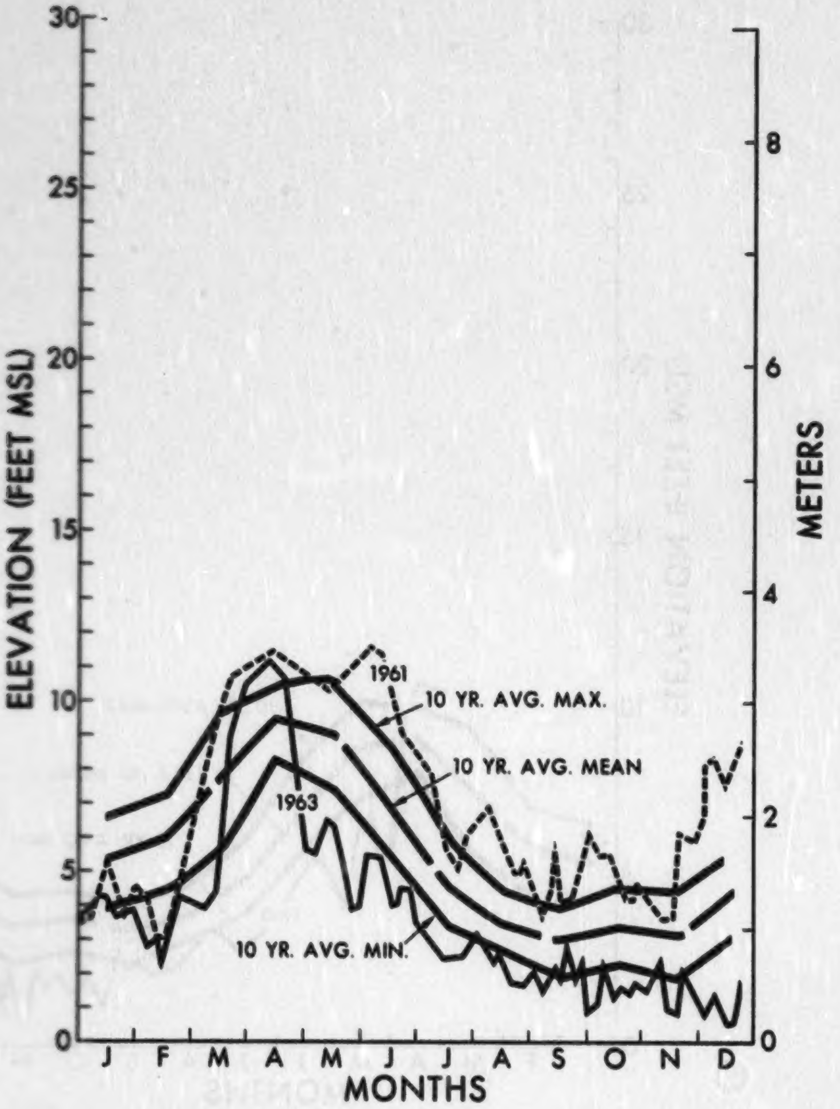

Figure A-23. Stage hydrographs at Grand Lake at Charenton, Station 12, from records 1961 through 1970.

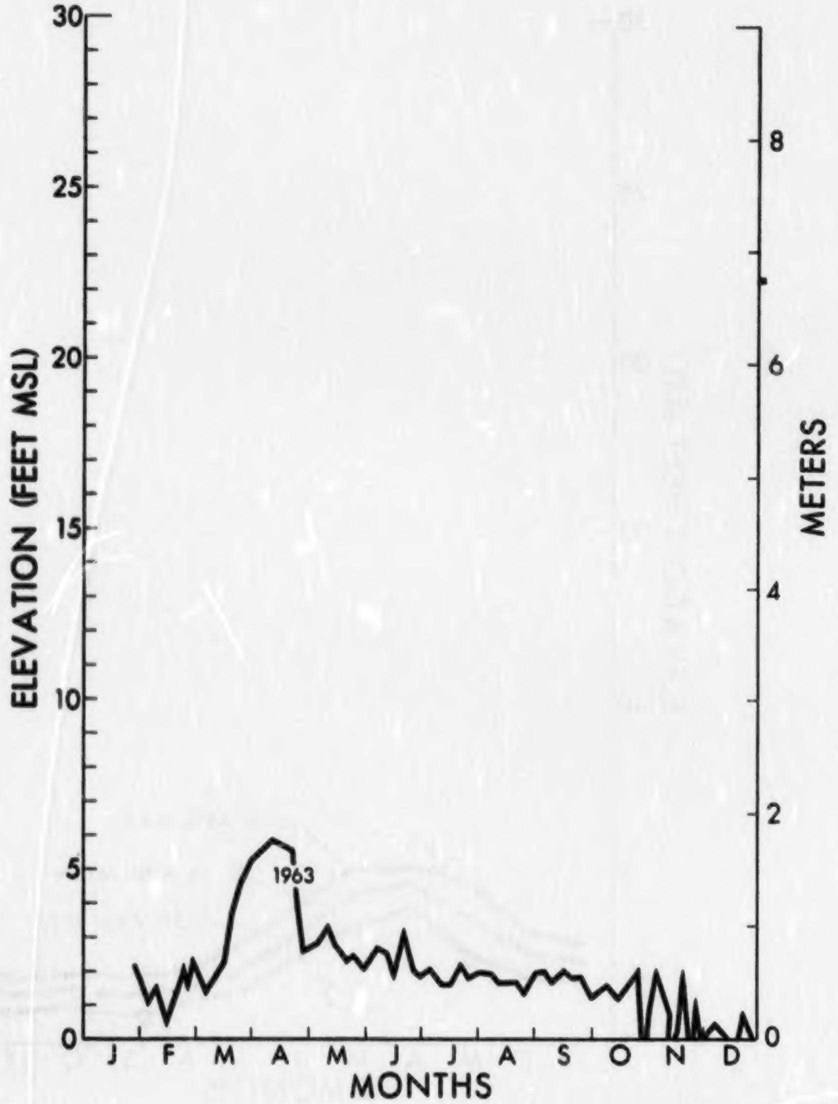

Figure A-24. Stage hydrographs at Cypress Pass, Station 14, from records 1961 through 1970.

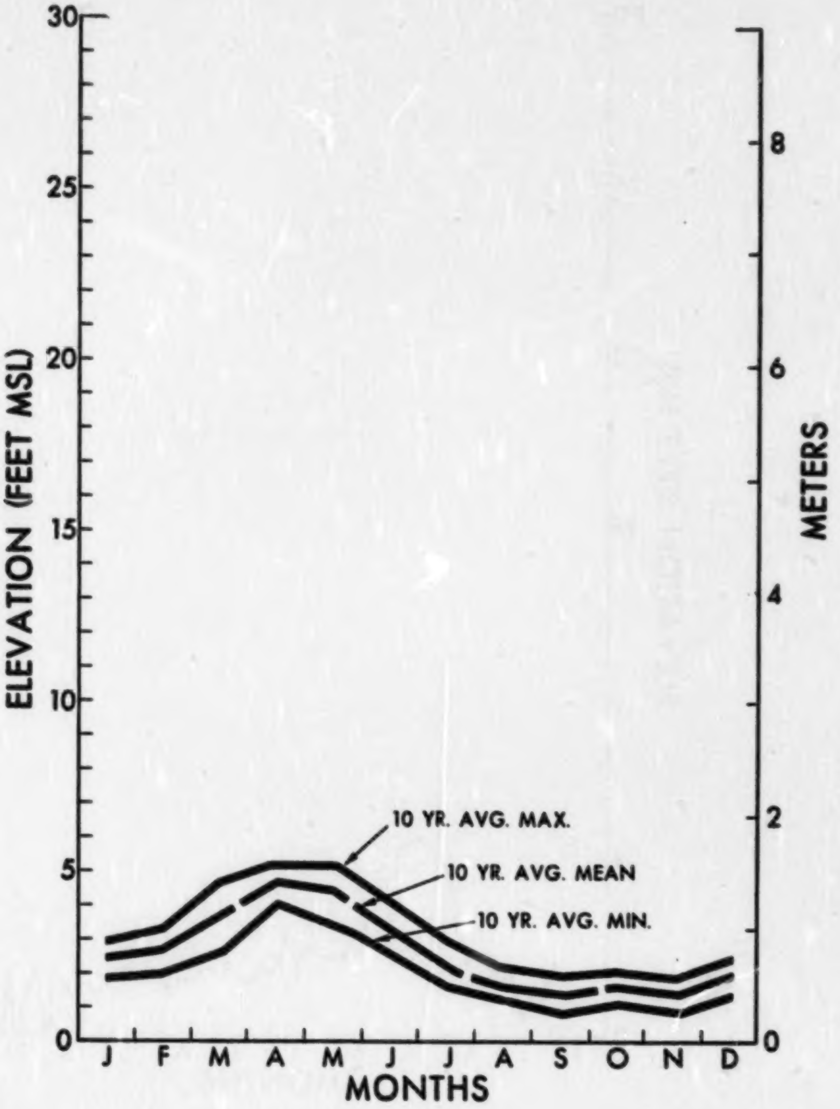

Figure A-25. Stage hydrographs at Little Bayou Sorrel at GIWW, Station 9B, from records 1961 through 1970.

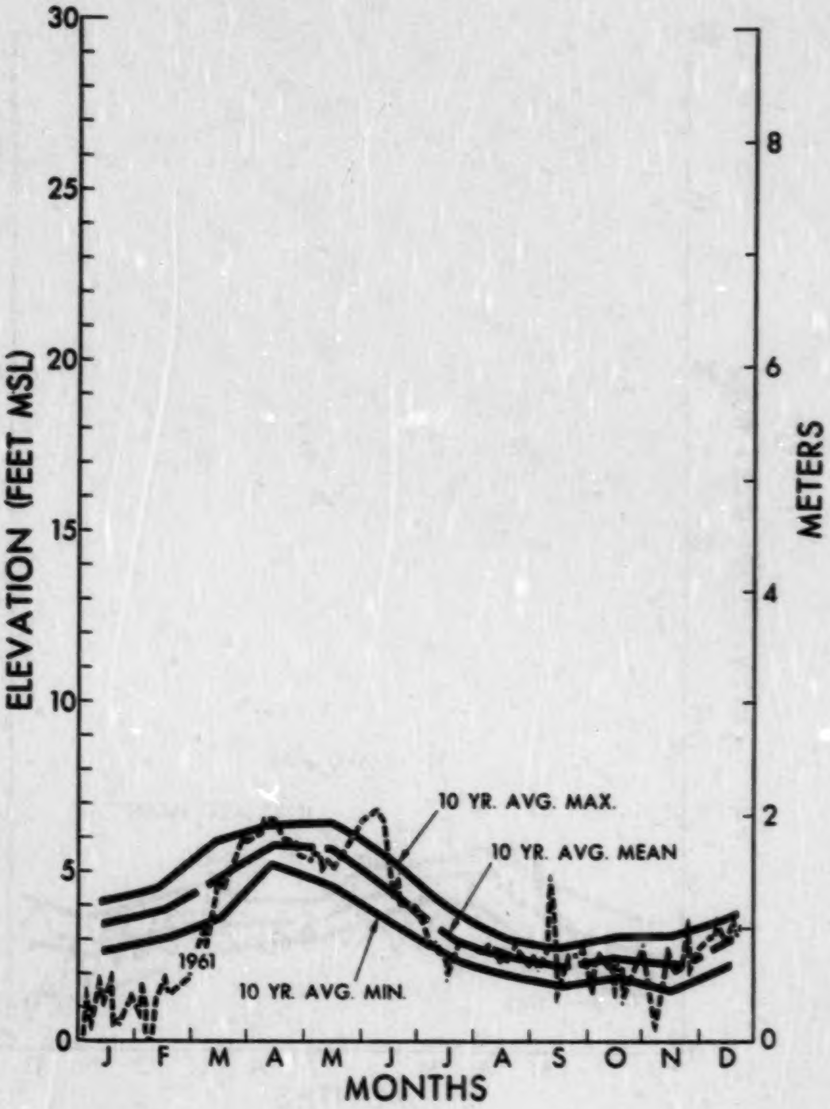

Figure A-26. Stage hydrographs at Six Mile Lake at Verdunville, Station 15, from records 1961 through 1970.

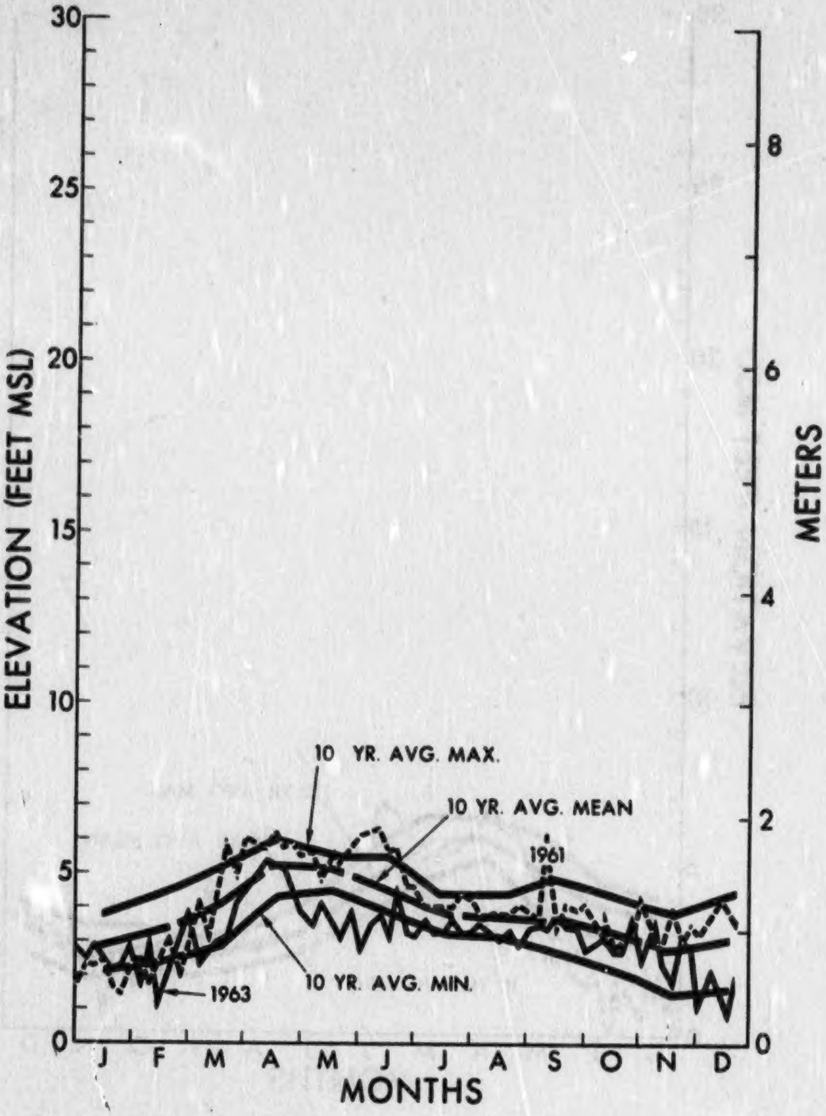

Figure A-27. Stage hydrographs at Wax Lake Outlet, Station 16, from records 1961 through 1970.

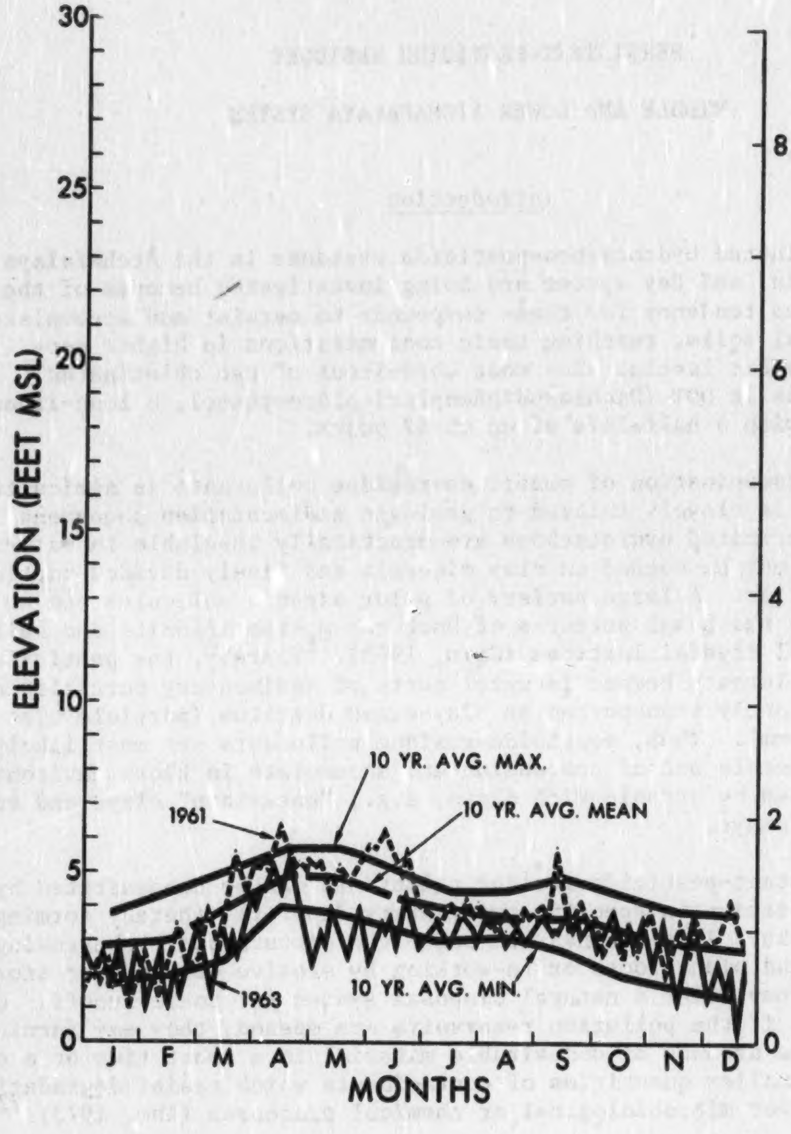

Figure A-28. Stage hydrographs at Lower Atchafalaya River at Morgan City, Station 19, from records 1961 through 1970.

Appendix B

PERSISTENT-PESTICIDE RESIDUES

MIDDLE AND LOWER ATCHAFALAYA SYSTEM

Introduction

Chlorinated hydrocarbon-pesticide residues in the Atchafalaya River, Basin, and Bay system are being investigated because of the demonstrated tendency for these compounds to persist and accumulate in agricultural soils, reaching toxic concentrations in higher ecological trophic levels. The most ubiquitous of the chlorinated hydrocarbons is DDT (Dichlorodiphenyltrichloroethane), a long-lived pollutant with a half-life of up to 17 years.

The dissemination of pesticide-residue pollutants in agricultural watersheds is closely related to geologic sedimentation phenomena. Even though chlorinated hydrocarbons are practically insoluble in water, many pesticides may be sorbed on clay minerals and finely divided particulate organic matter. A large variety of polar organic molecules can be absorbed on the basal surfaces of both the montmorillonite and halloysite clay-mineral crystal lattices (Grim, 1968).[71] Thereby, the pesticide-residue pollutants become integral parts of sedimentary particles and are subsequently transported as clay-sized detritus (particle size less than 1/256 mm). Thus, pesticide-residue pollutants are most likely to initially settle out of suspension and accumulate in those environments characterized by organic-rich clays, e.g., "backswamp" clays and some "prodelta" clays.

Persistent-pesticide-residue pollutants can be concentrated by natural processes in specific sedimentary deposits, thereby forming natural sinks. If the sinks are safe from disturbance by burrowing organisms and plant roots or re-working by erosive currents or storm activity, they offer a natural disposal system for toxic runoff. On the other hand, if the pollution reservoirs are opened, they may furnish either large amounts of undesirable material in a short time or a sustained influx of smaller quantities of contaminants which resist degradation through either microbiological or chemical processes (Ahr, 1973).[72]

The most common post-depositional processes which relocate DDT are burrowing and mixing by crabs, worms, and other organisms. Burrowing activity can be an effective agent for relocation of pollutants by 1) physical mixing; 2) generation of open canals for continuous

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71. R. E. Grim, Clay Mineralogy (McGraw-Hill, 1968), 596 pp.

72. W. M. Ahr, Long-Lived Pollutants in Sediments from the Laguna Atascosa National Wildlife Refuge, Texas (Bull., Geol. Soc. Amer., Vol. 84, August, 1973), pp. 2551-2516.

circulation of surface fluids deep into the substrate; and, 3) ingestion at one site and excretion at another. During ingestion and excretion of DDT by burrowing organisms some DDT can be metabolized to DDE (dichlorodiphenylethylene) (Ahr, 1973).[73]

Degradation of persistent-pesticide residues--i.e., any measurable chemical change in the pesticide molecule--can occur as either partial degradation to other organic intermediates or complete degradation to inorganic end products. Degradation can occur as the result of the activity of microorganisms or chemical processes. Fungi apparently do not actively degrade DDT, while some actinomycetes and a number of bacteria do. Biodegradation of some chlorinated hydrocarbon pesticides, including DDT, is enhanced under anaerobic conditions. DDT degrades more rapidly in soils under biologically active, anaerobic conditions compared with well-aerated systems, with DDD (dichlorodiphenyldichloroethane) as the major degradation product. Degradation or disappearance of DDT is accompanied by an increase in the level of DDD. A rather large group of facultative and obligate anaerobic bacteria are capable of affecting this transformation under anaerobic, but not aerobic, conditions. Studies utilizing the bacteria Aerobacter aerogenes show that the principal pathway of anaerobic biodegradation of DDT proceeds by direct reductive dechlorination to DDD, without the intermediate formation of DDE. Although the degradation of DDT to DDD involves the loss of only a single chlorine atom, it appears to be a necessary prerequisite for further degradation. Moreover, this conversion is a detoxification step since the mammalian toxicity of DDD is one-tenth that of DDT (Parr, Willis, and Smith, 1970a,[74] 1970b;[75] Willis, Parr, and Smith, 1971;[76] Smith and Parr, 1972).[77]

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[73] Ibid.

[74] J. F. Parr, G. H. Willis, and S. Smith, Soil Anaerobiosis: I Effect of Selected Environments and Energy Sources on Respiratory Activity of Soil Microorganisms (Soil Science, Vol. 110, No. 1, 1970a), pp. 37-43.

[75] J. F. Parr, G. H. Willis, and S. Smith, Soil Anaerobiosis: II Effect of Selected Environments and Energy Sources on the Degradation of DDT (Soil Science, Vol. 110, No. 5, 1970b), pp. 306-312.

[76] G. H. Willis, J. F. Parr, and S. Smith, Volatilization of Soil-Applied DDT and DDD from Flooded and Nonflooded Plots (Pesticides Monitoring Journal, Vol. 4, No. 4, March, 1971), pp. 204-208.

[77] S. Smith, and J. F. Parr, Chemical Stability of DDT and Related Compounds in Selected Alkaline Environments (Agricultural and Food Chemistry, Vol. 20, No. 4, July/August, 1972), pp. 839-841.

Since soil anaerobiosis can be achieved by merely submerging the soil with water, flooding has been suggested as a possible means of accelerating the degradation of persistent pesticides to less harmful compounds and allowing a more rapid decontamination of soil (Willis, Parr, and Smith, 1971).[78]

Comparatively little is known about chemical mechanisms which might also contribute to the degradation of DDT in soils. It has been reported that DDT adsorbed on homoionic clays was catalytically dehydrochlorinated to DDE, and that the reaction was influenced by the type of clay mineral and the exchange cations. The reaction was considerably enhanced with sodium compared with hydrogen clays. Whether this is a significant mechanism in natural soils has not been determined (Smith and Parr, 1972).[79]

The devastating environmental effect of chlorinated hydrocarbon pesticide residues is due to "biological magnification" of their toxicity, i.e., the systematic increase in pesticide residues with increase in ecological trophic level.

For example, Woodwell, Wurster, and Isaacson (1967)[80] investigated DDT residues in a salt marsh on the south shore of Long Island. Their results, shown in Table B-1, reveal that concentrations of DDT increase with trophic level through more than three orders of magnitude from 0.04 ppm in plankton to 75 ppm in a ring-billed gull. Highest concentrations occurred in scavenging and carnivorous fish and birds. Accumulation occurs either through direct absorption from the environment or by concentration along food chains. Birds near the top of these food chains have concentrations of DDT residue about a million times greater than the concentration in the water. Also, the shift in relative proportions of DDT, DDE, DDD with progression in trophic level is also conspicuous, from lower trophic levels in which organisms contain high proportions of DDT rather than metabolites, to upper levels where DDE is the most common residue (Woodwell, Wurster, and Isaacson, 1967).[81]

Woodwell, Wurster, and Isaacson (1967)[82] observe that residues in soil are leached by water, moved by erosion, and absorbed by mud-dwelling

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[78] G. H. Willis, et. al., 1971, op. cit.

[79] S. Smith, et. al., 1972, op. cit.

[80] G. M. Woodwell, C. F. Wurster, Jr., and P. A. Isaacson, DDT Residues in an East Coast Estuary: A Case of Biological Concentration of Persistent Insecticide (Science, Vol. 156, No. 3776, May, 1967), pp. 821-824.

[81] Ibid.

[82] Ibid.

TABLE B-1

DDT Residues from Woodwell, Wurster, and Isaacson (1967)[83]

DDT residues (DDT+DDE+DDD) (1) in samples from Carmans River estuary and vicinity, Long Island, N. Y., in parts per million wet weight of the whole organism, with the proportions of DDT, DDE, and DDD expressed as a percentage of the total. Letters in parentheses designate replicate samples.

Sample	DDT residues (ppm)	Percent of residue as		
		DDT	DDE	DDD
Water^{A}	0.00005			
Plankton, mostly zooplankton	.040	25	75	Trace
Cladophora gracilis	.083	56	28	16
Shrimp^{B}	.16	16	58	26
Opsanus tau, oyster toadfish (immature)^{B}	.17	None	100	Trace
Menidia menidia, Atlantic silverside^{B}	.23	17	48	35
Crickets^{B}	.23	62	19	19
Nassarius obsoletus, mud snail^{B}	.26	18	39	43
Gasterosteus aculeatus, threespine stickleback^{B}	.26	24	51	25
Anguilla rostrata, American ell (immature)^{B}	.28	29	43	28
Flying insects, mostly Diptera^{B}	.30	16	44	40
Spartina patens, shoots	.33	58	26	16
Mercenaria mercenaria, hard clam^{B}	.42	71	17	12
Cyprinodon variegatus, sheepshead minnow^{B}	.94	12	20	68
Anas rubripes, black duck	1.07	43	46	11
Fundulus heteroclitus, mummichog^{B}	1.24	58	18	24
Paralichthys dentatus, summer flounder^{C}	1.28	28	44	28
Esox niger, chain pickerel	1.33	34	26	40
Larus argentatus, herring gull, brain (d)	1.48	24	61	15
Strongylura marina, Atlantic needlefish	2.07	21	28	51
Spartina patens, roots	2.80	31	57	12
Sterna hirundo, common tern (a)	3.15	17	67	16
Sterna hirundo, common tern (b)	3.42	21	58	21
Butorides virescens, green heron (a) (immature, found dead)	3.51	20	57	23
Larus argentatus, herring gull (immature) (a)	3.52	18	73	9

TABLE B-1

DDT Residues from Woodwell, Wurster, and Isaacson (1967)[83]

Sample	DDT residues (ppm)	Percent of residue as		
		DDT	DDE	DDD
Butorides virescens, green heron (b)	3.57	8	70	22
Larus argentatus, herring gull, brain[D] (e)	4.56	22	67	11
Sterna albifrons, least tern (a)	4.75	14	71	15
Sterna hirundo, common tern (c)	5.17	17	55	28
Larus argentatus, herring gull (immature) (b)	5.43	18	71	11
Larus argentatus, herring gull (immature) (c)	5.53	25	62	13
Sterna albifrons, least tern (b)	6.40	17	68	15
Sterna hirundo, common tern (five abandoned eggs)	7.13	23	50	27
Larus argentatus, herring gull (d)	7.53	19	70	11
Larus argentatus, herring gull[D] (e)	9.60	22	71	7
Pandion haliaetus, osprey (one abandoned egg)[E]	13.8	15	64	21
Larus argentatus, herring gull (f)	18.5	30	56	14
Mergus serrator, red-breasted merganser (1964)[C]	22.8	28	65	7
Phalacrocorax auritus, double-crested cormorant (immature)	26.4	12	75	13
Larus delawarensis, ring-billed gull (immature)	75.5	15	71	14

[A] Estimated from Weaver *et*. *al* (4). [B] Composite sample of more than one individual. [C] From Captree Island, 20 miles (32 km) WSW of study area. [D] Found moribund and emaciated, north shore of Long Island. [E] From Gardiners Island, Long Island.

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[83] *Ibid*.

and mud-scavenging organisms; therefore, it is clear that the salt marsh ecosystem is not a suitable sink for pesticide-residue pollutants.

Ahr (1973)[84] investigated DDT residues in a coastal ecosystem on the flanks of the Rio Grande delta. His results, shown in Figure B-1, reveal that DDT is concentrated exponentially as the higher ecological levels of the coastal ecosystem are encountered. He concludes that when the rate of DDT concentration through ecological levels is considered, even small amounts (a few parts per billion) are harmful (Ahr, 1973).[85]

Ahr (1973)[86] also reports that extensive burrowing and mixing by biotic activity rules out this coastal environment as a suitable sink for pesticide-residue pollutants.

Woodwell, Wurster, and Isaacson (1967)[87] came to the interesting conclusion that analyses of water have limited meaning when evaluating the effects of DDT residues on animal populations. Water can be expected to contain a lower concentration of DDT than other components of an ecosystem--quantities that are usually vanishingly small or "nondetectable." Even these very low concentrations may be important because natural mechanisms can concentrate residues many thousands of times. A better criterion of hazard from DDT pollution would be analyses of carnivores or other organisms that concentrate the residues (Woodwell, Wurster, and Isaacson, 1967).[88]

Analytical Procedure

During August, 1973, water and soil samples were collected at six sites in the Six Mile Lake area of the Atchafalaya River Basin, north and west of Morgan City, Louisiana (Figure B-2). During September, October, and November, 1973, these samples were analyzed for chlorinated-hydrocarbon-pesticide residues.

A brief outline of the analytical methods used follows. Two ten-gram subsamples were drawn from each soil sample. These subsamples were run in duplicate analyses. Each subsample was extracted with 200-ml aliquots of a 1:1 solution of hexane and acetone. The samples were sonified with a Branson Model J-17A Sonifier Cell Disruptor for two 1.5-minute periods, each followed by decanting, filtering, and adding fresh aliquots of

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[84] W. M. Ahr, 1973, op. cit.

[85] Ibid.

[86] Ibid.

[87] G. M. Woodwell, et. al., 1967, op. cit.

[88] Ibid.

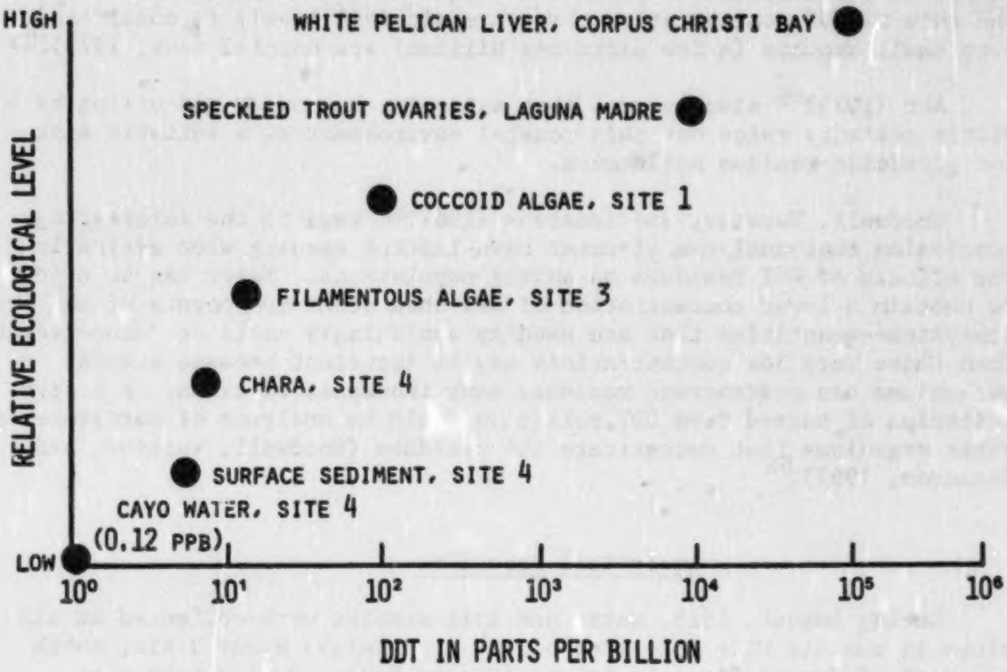

Figure B-1. DDT residues reported by Ahr (1973).[89] A plot of DDT against relative ecological level in the coastal environment covered by this study. Samples of water and plants were collected by W. M. Ahr. DDT data on fish and bird samples were furnished by Ray Childress, Texas Parks and Wildlife.

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[89] W. M. Ahr, 1973, op. cit.

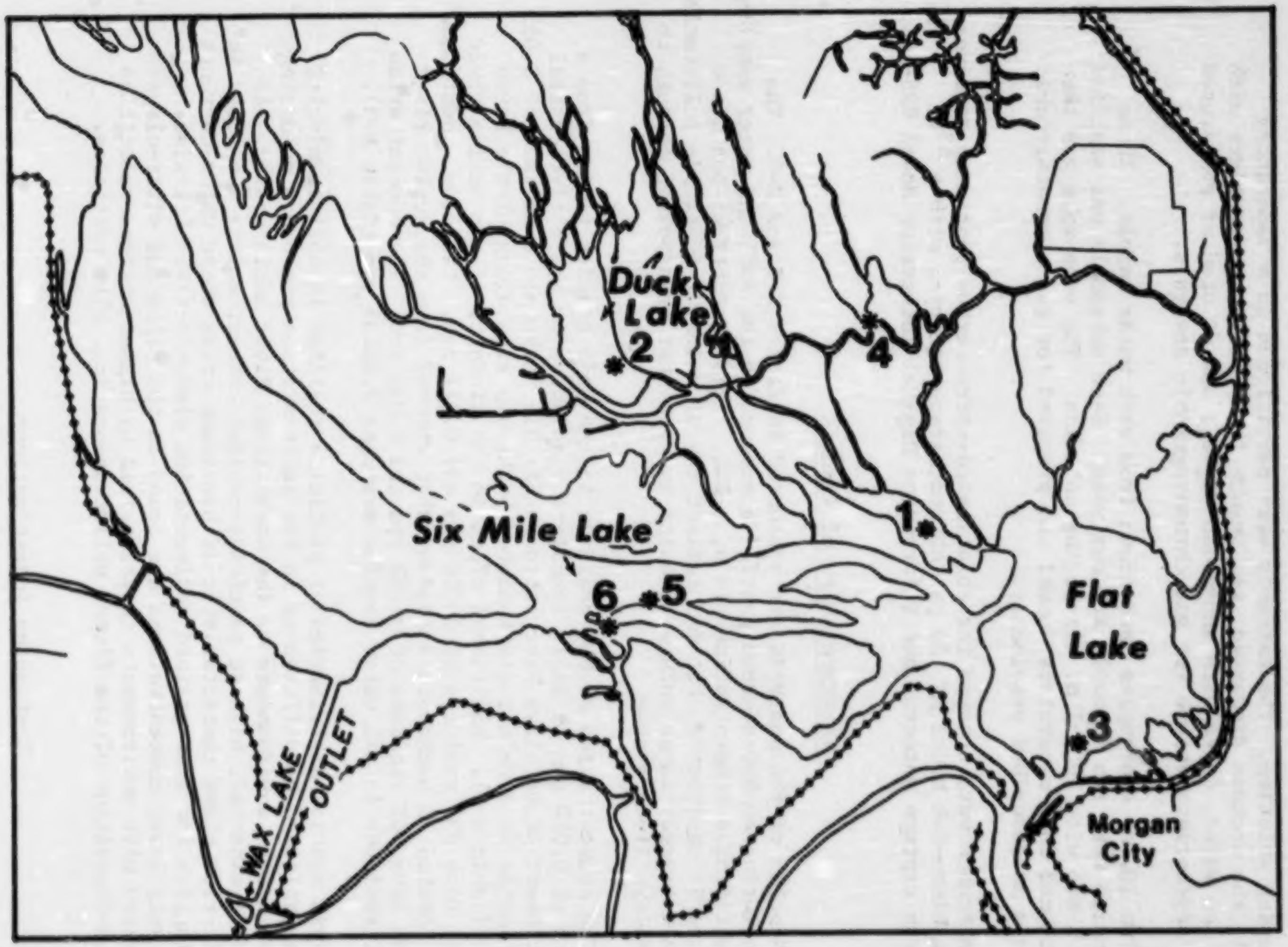

Duck Lake
2
4
1
Six Mile Lake
6
5
Flat Lake
3
Morgan City
WAX LAKE OUTLET

Figure B-2. Location of samples taken for pesticide analysis, Six Mile Lake area.

extracting solution. The extracts were partitioned in a separatory funnel, the acetone discarded, the hexane layer washed three times with distilled water, dried with anhydrous Na_2SO_4, and diluted or evaporated to an appropriate volume for gas chromatographic analysis.

Two 100-ml subsamples were drawn from each water sample. These subsamples were run in duplicate analyses. Each subsample was sonified for 1.5 min with 100 ml of extracting solution. The subsample was then partitioned in a separatory funnel and prepared for gas chromatographic analysis as described previously.

Aliquots were assayed for chlorinated-hydro-carbon-pesticide residues with a Micro-Tek Model MT 220 gas chromatograph equipped with a ^{63}Ni electron capture detector and Infotronics Digital Integrator Model CRS-100.

Interpretation of Results

Results of the analysis are presented in Tables B-2 and B-3. The only chlorinated-hydrocarbon pesticide present in the soil and water samples in identifiable concentrations is p, p-DDT. This scarcity of pesticide residues is unexpected, but may reflect the dilution of pesticide pollutants by the extremely large volume of water and sediment transported through the Atchafalaya River system.

The concentration of DDT residues in the soil samples ranges from a minimum of 0.010 ppm in soils immediately adjacent to the active channel of the Lower Atchafalaya River through Six Mile Lake, to a maximum of 0.055 ppm in soils in a relatively isolated backswamp area along Little Bayou Sorrel (Table B-2). Additional sites in the vicinity of the active river channel have DDT residues of 0.020 ppm and 0.027 ppm. Likewise, additional sites located in backswamp areas somewhat removed from the active river channel have DDT residues of 0.032 ppm and 0.035 ppm. The concentration of DDT residues in all water samples averages 0.00135 ppm (Table B-3).

This spatial distribution of pesticide residues in soil seemingly can be explained by differences in the sedimentation phenomena occurring in the various environments of the Atchafalaya River Basin system. As should be expected, highest pesticide-residue concentrations are found in organic-rich clays characteristic of backswamp areas where water currents are sluggish and fine-grained sedimentation predominates. Likewise, relatively lower concentrations are found in the silts and silty-clays associated with environments characterized by higher current velocities and non-deposition of the finer, pollutant-bearing, clay particles.

Continuing Investigations

Within the Atchafalaya River, Basin, and Bay system there appear to be two extensive regions which may possibly serve as natural sinks for the accumulation of pesticide-residue pollutants--the vast backswamp regions within the Atchafalaya River Basin, and the expanding prodelta environment marginal to the rapidly prograding delta in Atchafalaya Bay.

Table B-2 . DDT Concentrations in Bottom Sediment Samples from the Lower Middle Basin. Samples collected July 25 through August 7, 1973.

Sample No.	Ave. Peak Area	Conc. (mg/ l)	Vol. (ml)	Vol. (l)	Amount Found (mg)	Oven Dry Wt. Sample Extracted	ppm Found
S 1-1	1007	.003593	22.2	22,200	79.76	4.86	.016
S 1-2	3961	.014132	16.7	16,700	236.00	4.90	.048
S 2-1	2580	.009205	18.0	18,000	165.69	4.55	.036
S 2-2	2240	.007992	19.7	19,700	157.44	4.46	.035
S 3-1	1169	.004171	16.0	16,000	66.74	4.69	.014
S 3-2	684	.002440	18.3	18,300	44.65	4.63	.010
S 4-1	1804	.006436	18.1	18,100	116.49	2.11	.055
S 4-2	1859	.006632	17.4	17,400	115.40	2.16	.053
S 5-1	2212	.007892	15.0	15,000	118.38	4.22	.028
S 5-2	1609	.005740	19.0	19,000	109.06	4.16	.026
S 6-1	1887	.006732	19.1	19,100	128.58	6.05	.021
S 6-2	1700	.006065	18.6	18,600	112.81	5.97	.019

Table B-3 . DDT Concentrations in Surface Water Samples from the Lower Middle Basin. Samples collected July 25 through August 7, 1973.

Sample No.	Ave. Peak Area	Conc. (mg/ 1)	Vol. (ml)	Vol. (1)	Amount Found (mg)	Aliquot Extracted (ml)	ppm found
W 1-1	3260	.013629	6.9	6900	94.0	100	.00094
W 1-2	3069	.012830	8.6	8600	110.3	100	.00110
W 2-1	2048	.008562	12.6	12600	107.9	100	.00108
W 2-2	2238	.009356	10.0	10000	93.6	100	.00094
W 3-1	4399	.018391	9.6	9600	176.6	100	.00177
W 3-2	3218	.013453	8.0	8000	107.6	100	.00108
W 4-1	13379	.055934	11.9	11900	665.6	100	.00666
W 4-2	16032	.067025	8.7	8700	583.1	100	.00583
W 5-1	9259	.038709	8.0	8000	309.7	100	.00310
W 5-2	2060	.008612	9.5	9500	81.8	100	.00082
W 6-1	662	.002768	8.3	8300	23.0	100	.00023
W 6-2	577	.002412	9.2	9200	22.2	100	.00022

Unfortunately, the prodelta environment seems to be an unsatisfactory location for a sink because the pollutant-bearing clays are continuously being resuspended by wave action and incorporated into the dominant westward coastal current. This, in effect, serves to continuously recontaminate an extremely large area of the coastal zone. Also, the magnitude of "biological magnification" of pesticide-residue toxicity through the food chains in the prodelta environment is unknown and may possibly have disastrous environmental, and economic effects.

The backswamp environment does not undergo continuous reworking like the prodelta; instead, most backswamp areas experience a cycle of periodic flooding followed by dewatering. This flooding/dewatering cycle could possibly hinder the anaerobic biodegradation of DDT and other chlorinated hydrocarbon pesticides, and thus allow toxic pollutants to accumulate in harmful concentrations. As with the prodelta environment, the magnitude of "biological magnification" of toxicity through the food chains in the backswamp environment is not well understood and may have equally disastrous effects.

Additional sampling will be conducted in order to properly evaluate the accumulation of persistent-pesticide-residue pollutants in these two environments.

Under controlled laboratory conditions, known concentrations of pesticides will be introduced into soil samples from these two environments. The samples will then be incubated in an aerobic condition in order to evaluate the ability of the microorganism population to degrade persistent pesticides to less harmful compounds. By this experiment it is hoped to be able to gauge the capacity of the environment to decontaminate itself.

SECTION XIII

GLOSSARY

Accretion - Building of or increase in area of land or subaqueous deposits by natural processes, such as during the growth of a point bar or beach.

Aggradation - The process of building up of a surface by deposition, continuous or intermittent.

Artificial Levee - Man-made dike along the side of a river channel erected to prevent overflow during floods.

Bar - A deposit of alluvium either in a channel or along its side, commonly composed of coarser sediment than that underlying it; also a shoal area near shore or out in a lake, bay,etc.

Basin - A low area toward which streams flow from natural levees, adjacent hills, etc.; a depression of the sea floor more or less equidimensional in form and of variable extent.

Borrow pit - An excavated area where material has been borrowed for use as fill at another location.

Canal - Ordinarily a man-made excavation connecting streams or bodies of water for such purposes as navigation, drainage, or irrigation; in some cases, natural channels that are narrow in proportion to length.

Channel - A natural or artificial waterway containing matter which is moving continuously or intermittently; the confined area down which a stream flows.

Crevasse - Overflow during flood, or less commonly, from other causes, such as in a place weakened by holes bored by animals or where rocks are weakened along faults. Also refers to distinctive patterns of ridges and swales resulting from sediment deposition in vicinity of such a break.

Coast - The general region of indefinite width that extends from the sea inland to the first major change in terrain features.

Discharge - The rate of flow of water or ice from a river, fiord, or harbor at a given instant in terms of volume per unit time, for example, cubic feet per second.

Delta - An alluvial deposit, usually triangular, at the mouth a river, stream, or tidal inlet.

Deterioration - The action or process of making inferior in quality or value.

Detritus - Loose material derived from rock disintegration, ordinarily mechanically. Most detrital material in the study area has been introduced through river transport.

Diapiric - Of or pertaining to a piercing fold; anticlines in which a mobile core, such as salt, has injected the more brittle overlying rock.

Distributary - Channel branching from another in the direction of water flow, particularily if it does not rejoin farther downstream.

Diurnal - Daily, especially pertaining to actions which are completed within 24 hours and recur every 24 hours.

Diversion - A change in downstream course that as applied to streams, is permanent or comparatively so; generally initiated at time of flood overflow.

Environment - The sum total of all the external conditions which may affect an organism, community, material, or energy, if brought under the influence of external conditions.

Environmental units - Mappable units having similar suites of environmental characteristics.

Erosion - Any or all processes by which soil or rock is broken up and transported from one place to another.

Fault - Fracture in rock accompanied by lateral or vertical displacement of a block on one side relative to that on the other.

Floodbasin - A tract actually covered by water during the highest floods, or the flat area between the sloping low plains on one side and the river lands on the other, commonly having a strictly swampy vegetation.

Flow regime - Characteristics of flow and sediment transport of a stream system.

Fluvial - Pertaining to channels of water, i.e., streams, creeks, river, etc.

Hummock - A mound or knoll; a small elevation.

Inlier - A space occupied by one formation which is completely surrounded by another; a more or less circular or elliptical area of older rocks surrounded by younger strata.

Intrusive - In petrology, while fluid, having penetrated into or between other rocks, but solidifying before reaching the surface.

Lacustrine - Produced by or belonging to lakes.

Management unit - Clusters of environmental and land use units delineated for planning purposes.

Marsh - A low, relatively flat area which is wet for appreciable periods and commonly contains considerable water surface, supporting widespread vegetational cover of grasses and other plants smaller than trees or large bushes.

Meander - To develop systematic sinuosity as a result of processes of deposition, sediment entrainment, etc.

Mudflat - A muddy or sandy coastal strip usually submerged by high tide.

Natural levee - A ridge developed at times of flood as a result of localized deposition along banks of channels, or submerged along sides of threads of flow in deltas, characteristic of alluviating streams.

Peat - Carbonaceous material resulting from partial decomposition of vegetation such as collects in shallow water or as a result of increase of volume, such as accumulations of moss that remain saturated with water in cool regions.

Plastic flow - Movement of rock material in response to pressure; little or no rigidity exhibited.

Point bar - The region lying back of a convex bend along a channel in which alluvium has been deposited, including the exposed parts of the wetland perimeter of the channel and extending back toward an adjacent basin.

Process-material-form relationship - Interactions of processes.

Prodelta - An area of river-derived clay deposition in the vicinity of active delta.

Progradation - A seaward advance of the shoreline resulting from the nearshore deposition of sediments brought to the sea by rivers.

Reef - Accumulations of organic skeletal components of marine organisms as mollusks, coral, or algae which may support a complex community of marine organisms.

Ridge - A long narrow topographic elevation, sides of which are variable, but distinctly slope away from a crest, which may be subaerial or marine.

Scour - The downward and sideward erosion of a sediment bed by wave or current action.

Sediment load - Sediment transported in a current, includes bed load, suspended load, and dissolved solids.

Sedimentation - The process of breakup and separation of particles from the parent rock, their transportation, deposition, and consolidation into another rock.

Shoal - Any area surrounded by deeper water, whether in a river or body of standing water.

Spoil - Material deposited after excavation; i.e., bank of sediment at side of dredged waterways, as along canals, left by dumping draglines, shovels, etc.

Storm surge - A rise above normal water level on the open coast due only to the action of wind stress on the water surface.

Subaqueous - Under the surface of water.

Succession - The replacement of one community by another.

Swamp - Low, wet area covered by trees or high bushes, as distinguished from marsh.

System - A regularly interacting or interdependent group of related natural objects or forces, such as a river system.

Systems approach - The application of systems theory to organizing and analyzing data pertaining to natural and human systems.

Systems theory - Consideration of the makeup and interactions of natural and human systems. A system is an assemblage of objects united by some form or regular interaction or interdependence; an organic or organized whole, as the solar system.

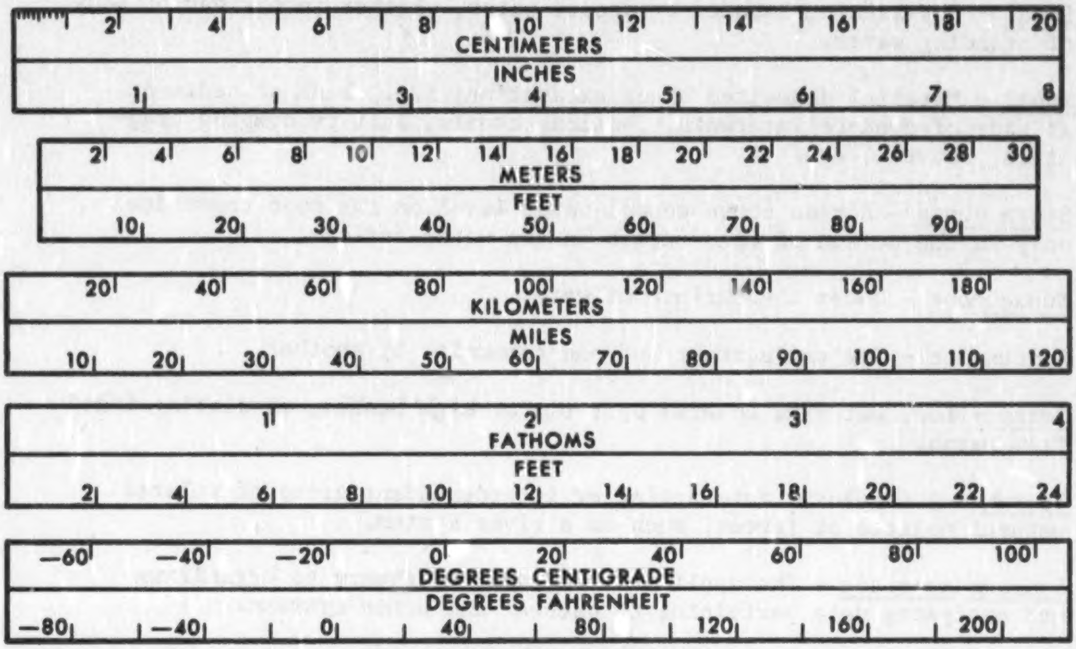
Tectonic - Of or pertaining to, or designating the rock structure and external forms resulting from the deformation of the earth's crust, includes movements and resulting structural elements.

Terrace - Relatively flat surface at some elevation above another. An alluvial terrace is an abandoned flood plain no longer subject to flooding because it stands higher than areas submerged at times of bank overtopping.

Tidal range - The difference in height between consecutive high and low waters. Where the type of tide is diurnal, the mean range is the same as the diurnal range.

Weir - Submerged barrier to flow, typically of artificial origin, for example, for the purpose of deflecting flow direction into the head of a canal.

CONVERSION TABLE


2 4 6 8 10 12 14 16 18 20
CENTIMETERS
INCHES
1 3 4 5 6 7 8
2 4 6 8 10 12 14 16 18 20 22 24 26 28 30
METERS
FEET
10 20 30 40 50 60 70 80 90
20 40 60 80 100 120 140 160 180
KILOMETERS
MILES
10 20 30 40 50 60 70 80 90 100 110 120
1 2 3 4
FATHOMS
FEET
2 4 6 8 10 12 14 16 18 20 22 24
−60 −40 −20 0 20 40 60 80 100
DEGREES CENTIGRADE
DEGREES FAHRENHEIT
−80 −40 0 40 80 120 160 200

CONVERSION FACTORS

LENGTH

1 inch	= 2.54 centimeters	1 centimeter	= 0.40 inch
1 inch	= 25.40 millimeters	1 millimeter	= 0.04 inch
1 foot	= 0.30 meter	1 meter	= 3.28 feet
1 yard	= 0.91 meter	1 meter	= 1.09 yards
1 fathom	= 1.83 meters	1 meter	= 0.55 fathom
1 fathom	= 6.00 feet	1 meter	= 39.37 inches
1 foot	= 0.17 fathom	1 meter	= 100 centimeters
1 mile	= 1.61 kilometers	1 kilometer	= 0.62 mile
1 mile	= 1609.34 meters	1 kilometer	= 1000 meters
1 mile	= 5280 feet	1 kilometer	= 3280.84 feet

AREA

1 foot^2	= 0.09 meter^2	1 meter^2	= 10.76 feet^2
1 yard^2	= 0.84 meter^2	1 meter^2	= 1.20 yards^2
1 mile^2	= 2.59 kilometers^2	1 kilometer^2	= 0.39 mile^2
1 acre	= 0.40 hectare	1 hectare	= 2.47 acres

VOLUME AND CAPACITY

1 foot^3	= 0.03 meter^3	1 meter^3	= 35.31 feet^3
		1 meter^3	= 264.17 gallons (US)

VELOCITY

1 foot/second	= 0.68 mile/hour	1 meter/second	= 3.60 kilometers/hour
1 foot/second	= 1.10 kilometers/hour	1 meter/second	= 2.24 miles/hour
1 foot^3/second	= 0.03 meter^3/second	1 meter^3/second	= 35.31 feet^3/second
1 mile/hour	= 1.47 feet/second	1 kilometer/hour	= 0.91 foot/second
1 mile/hour	= 0.45 meter/second	1 kilometer/hour	= 0.28 meter/second

TEMPERATURE

°Fahrenheit	= 9/5 (°C + 32)	°Centigrade	= 5/9 (°F - 32)

The literature section of this Report is divided into two sections. Section XIV - REFERENCES - is an alphabetical listing of research material which has been both cited and footnoted in the main text. Section XV - BIBLIOGRAPHY - is a more complete listing of the literature available on The Atchafalaya Basin and its associated resources.

SECTION XIV

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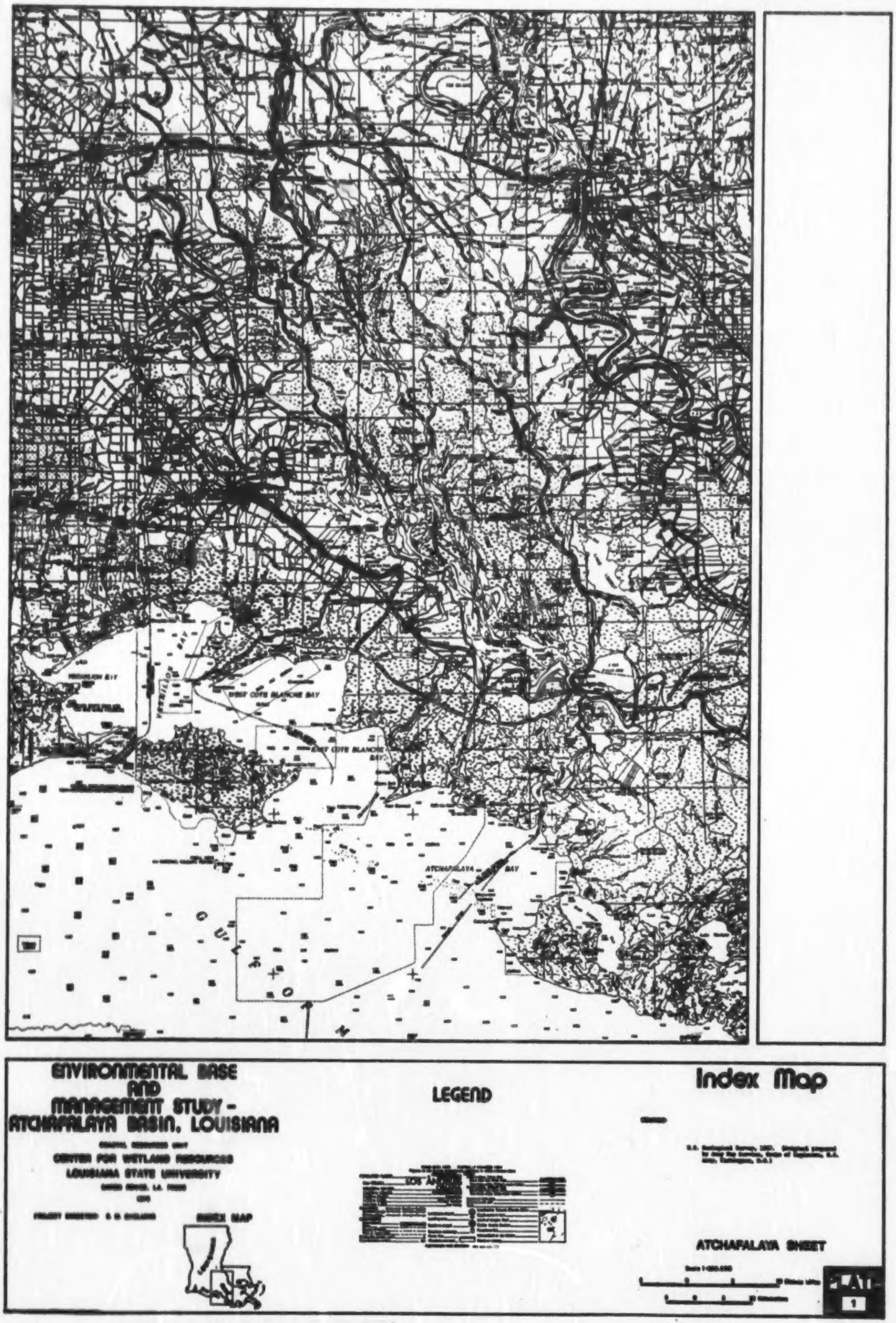
SECTION XVI

Appendix C

Plates of the Environmental Base


WEST COTE BLANCHE BAY
EAST COTE BLANCHE BAY
ATCHAFALAYA BAY
ENVIRONMENTAL BASE AND MANAGEMENT STUDY - ATCHAFALAYA BASIN, LOUISIANA
CENTER FOR WETLAND RESOURCES
LOUISIANA STATE UNIVERSITY
INDEX MAP
LEGEND
Index Map
ATCHAFALAYA SHEET
PLATE
1

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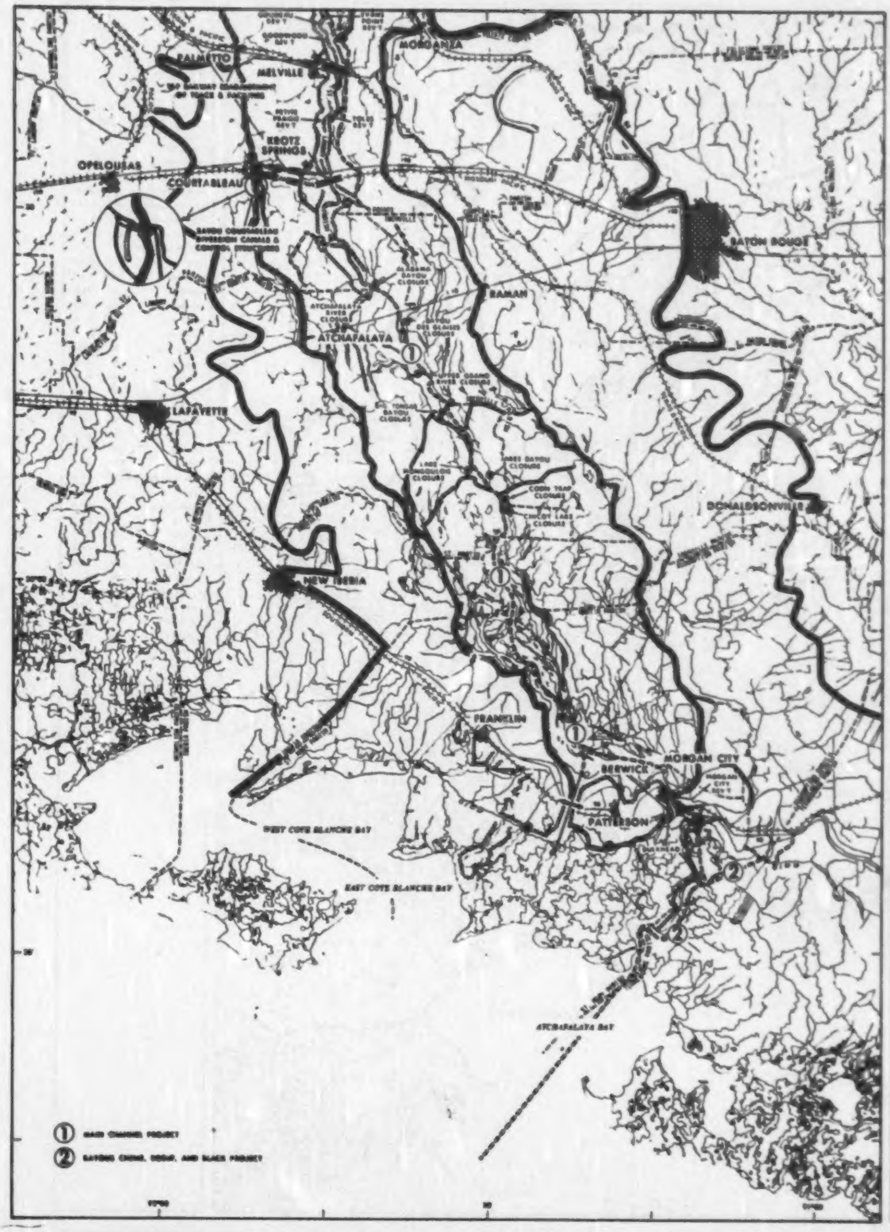
PALMETTO
MELVILLE
MORGANZA
KROTZ SPRINGS
OPELOUSAS
COURTABLEAU
BATON ROUGE
RAMAH
ATCHAFALAYA
LAFAYETTE
DONALDSONVILLE
NEW IBERIA
FRANKLIN
MORGAN CITY
BERWICK
PATTERSON
WEST COTE BLANCHE BAY
EAST COTE BLANCHE BAY
ATCHAFALAYA BAY
① MAIN CHANNEL PROJECT
② BAYOUS CHENE, BOEUF, AND BLACK PROJECT

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BATON ROUGE LA 70803

PROJECT DIRECTOR S M GAGLIANO

INDEX MAP

LEGEND

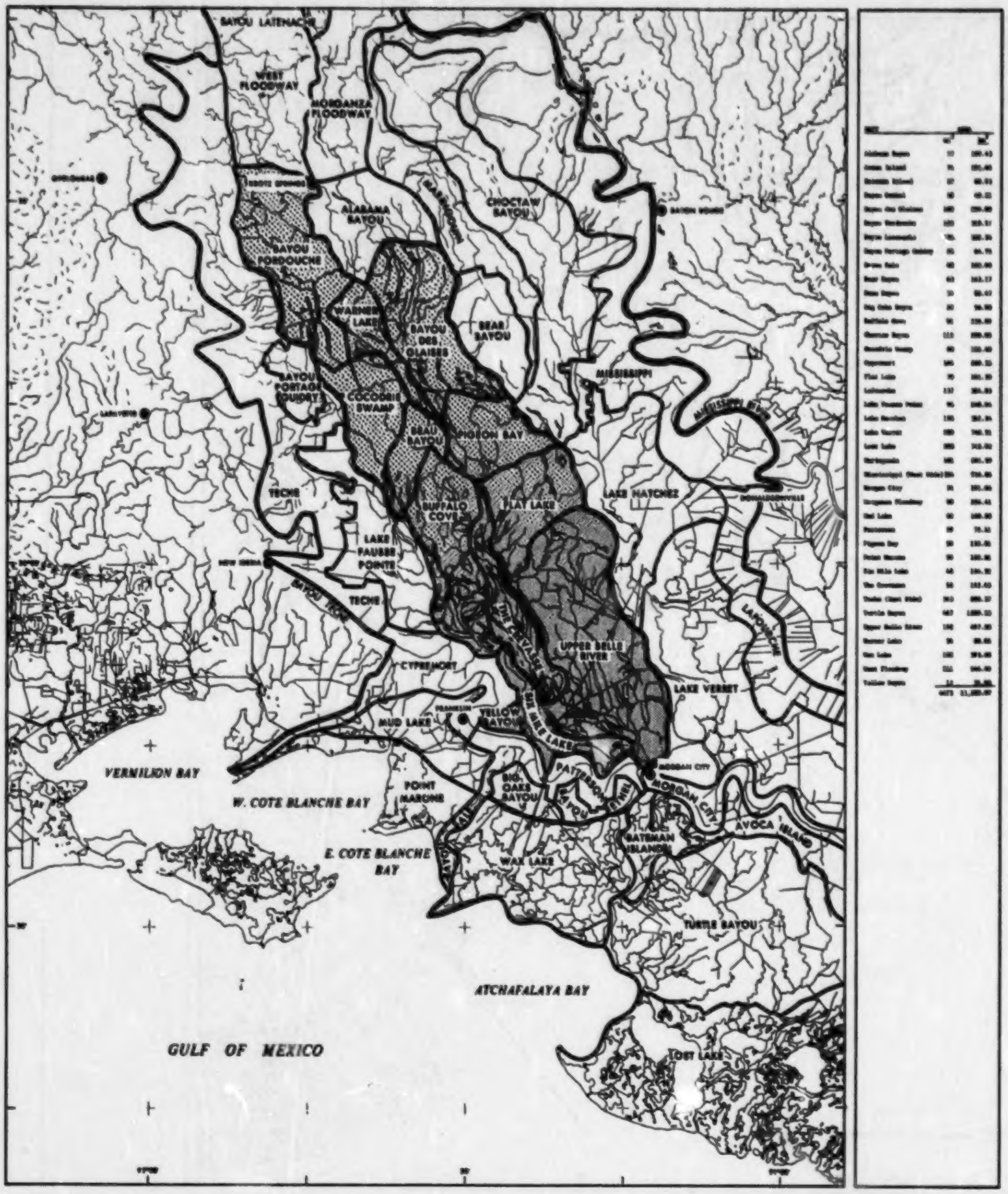
	Completed	Authorized	Under Construction
Levee	—	—	—
Channel	—	- - -	
Gated Culvert	⊢⊣		
Floodgate	▬		
Lock	●		
Pumping Plant	•		
Drainage Structure	●	○	
Road on Levee	—		

▬ Study Area Boundary

Flood Control and Drainage Works

ATCHAFALAYA SHEET

PLATE
8



BAYOU LATENACHE
WEST FLOODWAY
MORGANZA FLOODWAY
ALABAMA BAYOU
CHOCTAW BAYOU
BAYOU FORDOCHE
WARNER LAKE
BAYOU DES GLAISES
BEAR BAYOU
BAYOU PORTAGE GUIDRY
COCODRIE SWAMP
PIGEON BAY
MISSISSIPPI
MISSISSIPPI RIVER
TECHE
BUFFALO COVE
FLAT LAKE
LAKE HATCHEZ
DONALDSONVILLE
LAKE FAUSSE POINTE
NEW IBERIA
BAYOU TECHE
UPPER BELLE RIVER
CYPREMORT
LAKE VERRET
FRANKLIN
YELLOW BAYOU
MUD LAKE
SIX MILE LAKE
VERMILION BAY
W. COTE BLANCHE BAY
POINT MARONE
BIG OAKS BAYOU
PATTERSON
MORGAN CITY
AVOCA ISLAND
E. COTE BLANCHE BAY
WAX LAKE
BATEMAN ISLANDS
TURTLE BAYOU
ATCHAFALAYA BAY
GULF OF MEXICO
LOST LAKE

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COMPILED BY: S. M. GAGLIANO
J. L. VAN BEEK

INDEX MAP

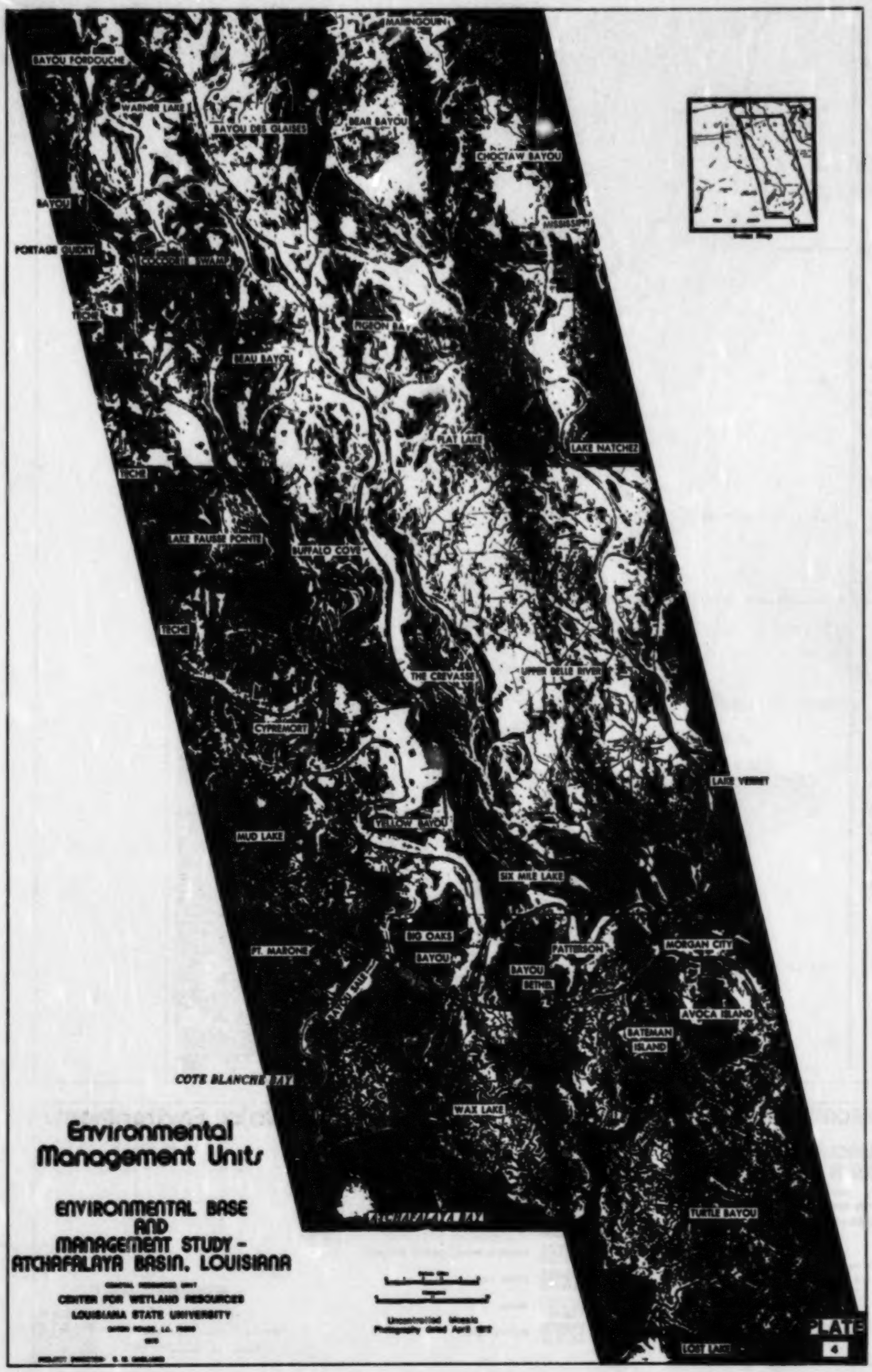
LEGEND

—	Unit Boundaries
▨	Area of Study Emphasis
—	Study Area Boundary

Environmental Management Units

ATCHAFALAYA SHEET

PLATE 8


MARINGOUIN
BAYOU FORDOUCHE
WARNER LAKE
BAYOU DES GLAISES
BEAR BAYOU
CHOCTAW BAYOU
BAYOU
MISSISSIPPI
PORTAGE GUIDRY
COCODRIE SWAMP
TECHE
PIGEON BAY
BEAU BAYOU
FLAT LAKE
LAKE NATCHEZ
TECHE
LAKE FAUSSE POINTE
BUFFALO COVE
TECHE
THE CREVASSE
UPPER BELLE RIVER
CYPREMORT
LAKE VERRET
YELLOW BAYOU
MUD LAKE
SIX MILE LAKE
BIG OAKS
BAYOU
PT. MARONE
PATTERSON
MORGAN CITY
BAYOU
BETHEL
BAYOU SALE
AVOCA ISLAND
BATEMAN
ISLAND
COTE BLANCHE BAY
WAX LAKE
ATCHAFALAYA BAY
TURTLE BAYOU
LOST LAKE
Index Map
Uncontrolled Mosaic
Photography dated April 1977
PLATE
4

Environmental Management Units

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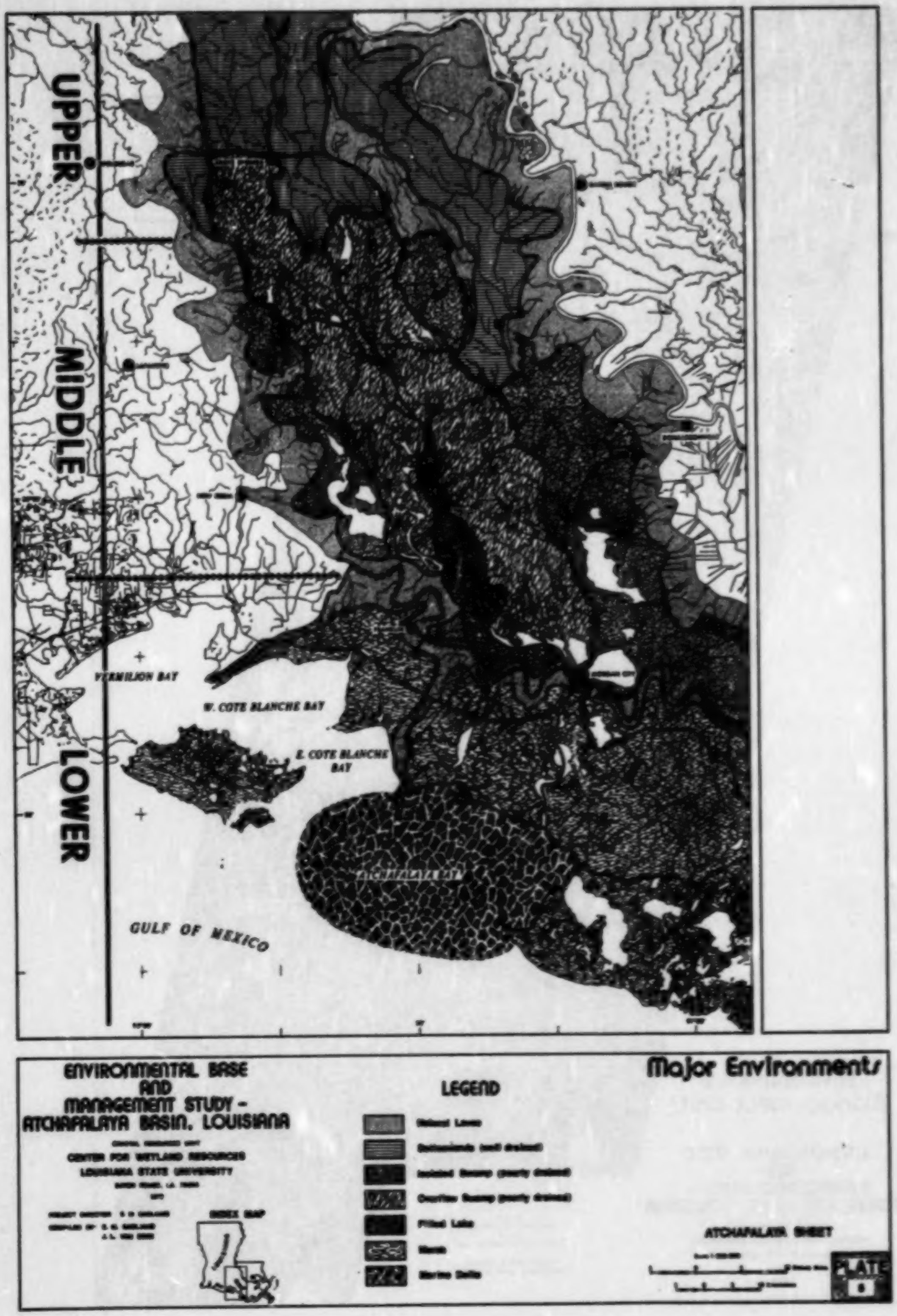
UPPER
MIDDLE
LOWER
VERMILION BAY
W. COTE BLANCHE BAY
E. COTE BLANCHE BAY
ATCHAFALAYA BAY
GULF OF MEXICO
ENVIRONMENTAL BASE AND MANAGEMENT STUDY - ATCHAFALAYA BASIN, LOUISIANA
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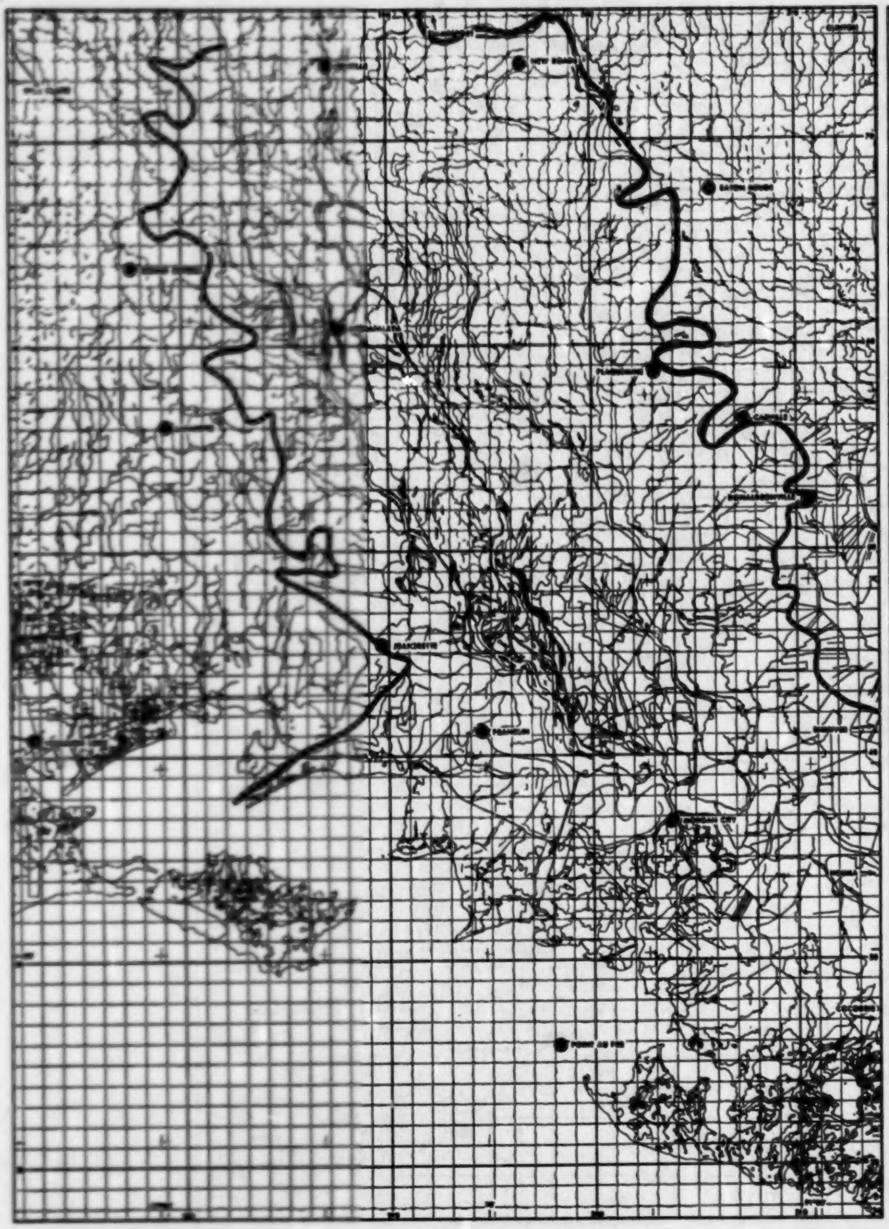
INDEX MAP
LEGEND
Natural Levee
Bottomlands (well drained)
Isolated Swamp (poorly drained)
Overflow Swamp (poorly drained)
Filled Lake
Marsh
Marine Delta
Major Environments
ATCHAFALAYA SHEET
PLATE
8



To facilitate and systematize data handling, a grid has been used that divides the area into equal-size squares 10,000 feet on the side. The grid is based on the 100,000 foot Louisiana Coordinate System (LCS), and each cell is identified by the coordinates of its lower left-hand corner. Coordinates are shown on the plate as fractions of the LCS coordinates.

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BATON ROUGE, LA [illegible]
[illegible]

PROJECT DIRECTOR [illegible]

INDEX MAP

Data Base Grid and Climatological Stations

━━━━ Study Area Boundary

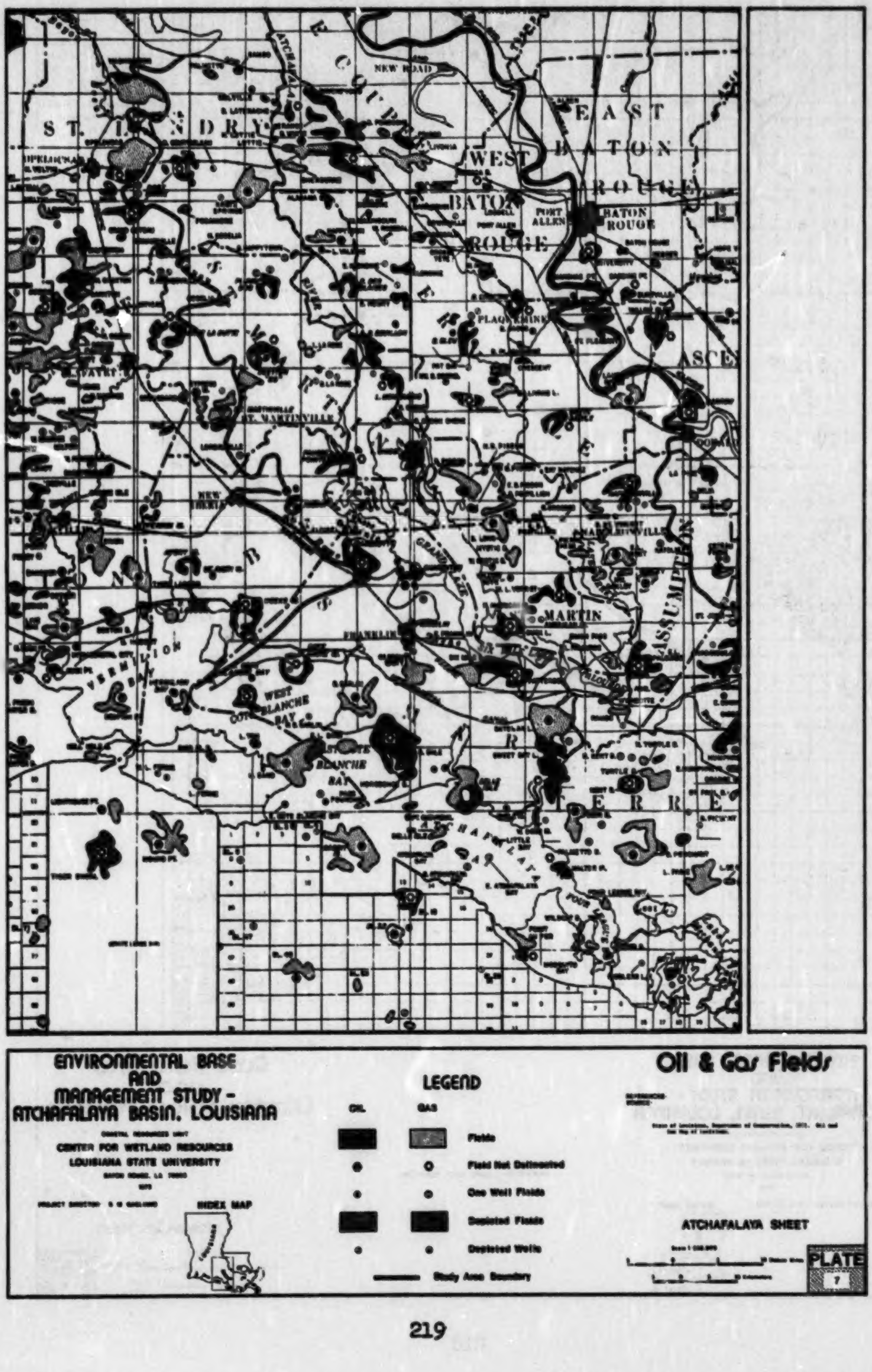
ATCHAFALAYA SHEET

Scale 1:250,000

[illegible] Statute Miles

[illegible] Kilometers

PLATE 8

ST. LANDRY
E COUPE
NEW ROAD
EAST BATON ROUGE
WEST BATON ROUGE
PORT ALLEN
BATON ROUGE
PLAQUEMINE
ST. MARTINVILLE
NEW IBERIA
VERMILION BAY
WEST COTE BLANCHE BAY
COTE BLANCHE BAY
FRANKLIN
MARTIN
ASSUMPTION
ATCHAFALAYA BAY
FOUR LEAGUE BAY
T E R R E
ASCE
ENVIRONMENTAL BASE AND MANAGEMENT STUDY - ATCHAFALAYA BASIN, LOUISIANA
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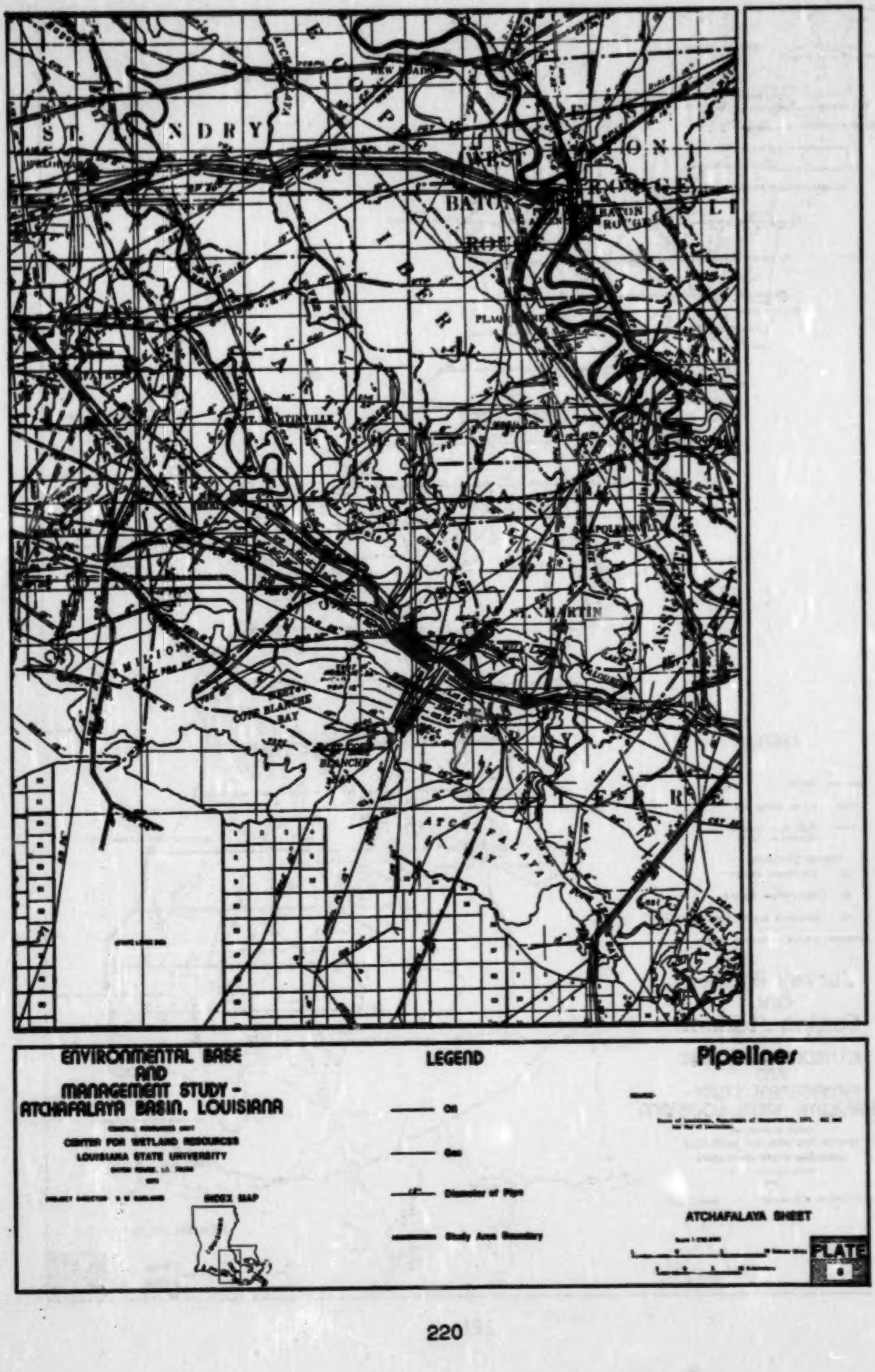
LOUISIANA STATE UNIVERSITY
INDEX MAP
LEGEND
OIL
GAS
Fields
Field Not Delineated
One Well Fields
Depleted Fields
Depleted Wells
Study Area Boundary
Oil & Gas Fields
ATCHAFALAYA SHEET
PLATE
7


ST. LANDRY
POINTE COUPEE
WEST BATON ROUGE
BATON ROUGE
IBERVILLE
ST. MARTIN
ST. MARTINVILLE
VERMILION
COTE BLANCHE BAY
WEST COTE BLANCHE BAY
ATCHAFALAYA BAY
ST. MARY
ASSUMPTION
INDEX MAP

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LEGEND

Oil

Gas

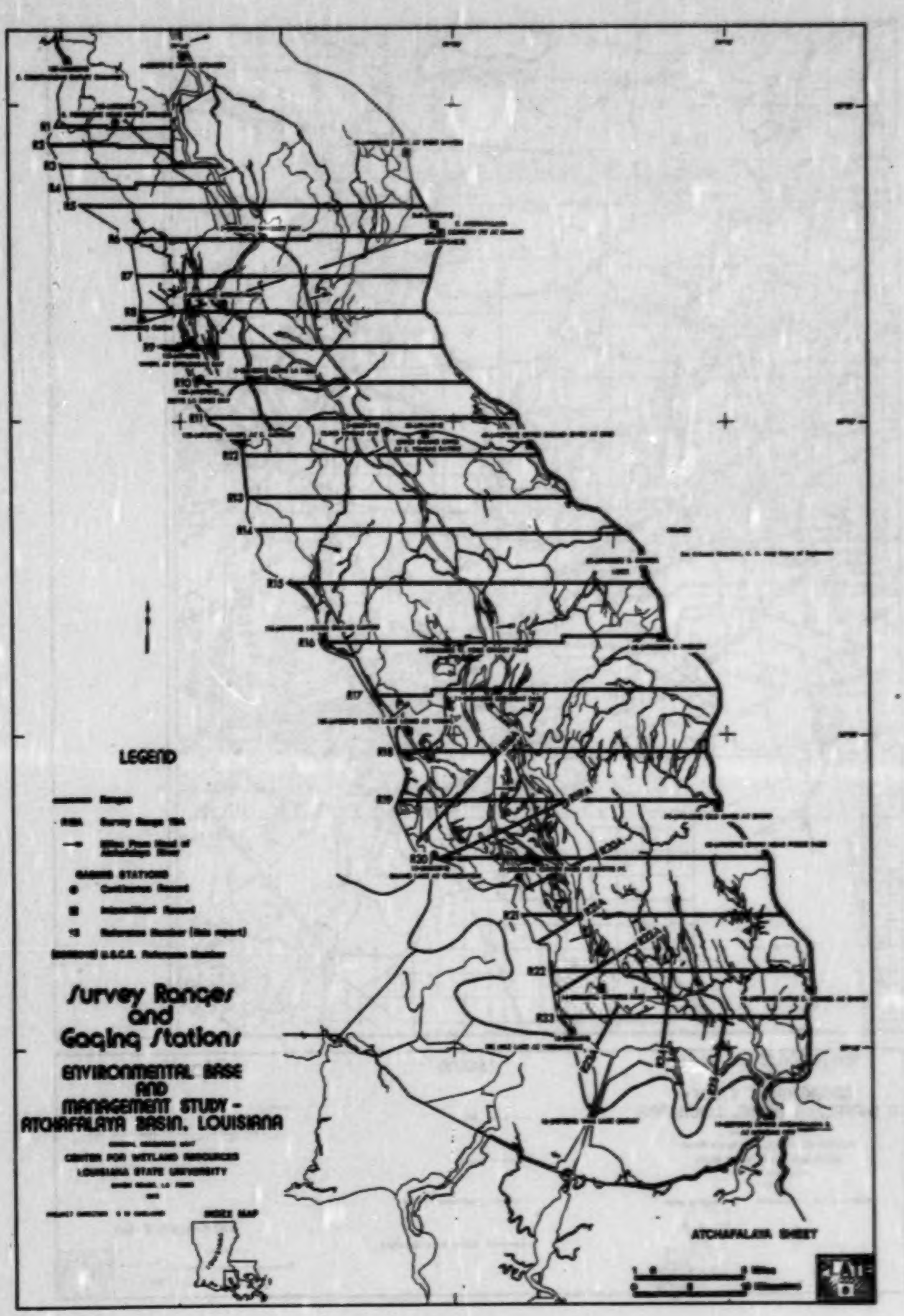
Diameter of Pipe

Study Area Boundary

Pipelines

ATCHAFALAYA SHEET

PLATE 8


R1
R2
R3
R4
R5
R6
R7
R8
R9
R10
R11
R12
R13
R14
R15
R16
R17
R18
R19
R20
R21
R22
R23
LEGEND
Ranges
Survey Range 19A
Miles From Head of Atchafalaya River
GAGING STATIONS
Continuous Record
Intermittent Record
Reference Number (this report)
U.S.C.E. Reference Number
Survey Ranges and Gaging Stations
ENVIRONMENTAL BASE AND MANAGEMENT STUDY - ATCHAFALAYA BASIN, LOUISIANA
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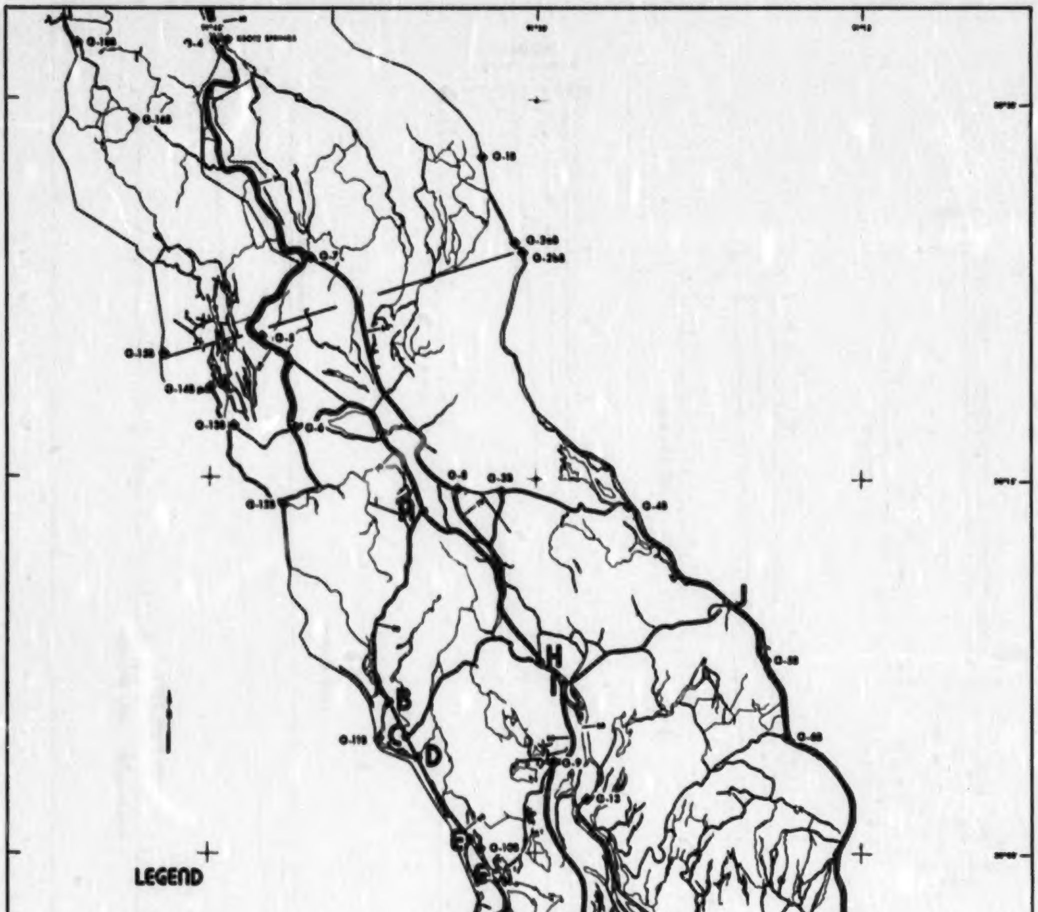
LOUISIANA STATE UNIVERSITY
INDEX MAP
ATCHAFALAYA SHEET
PLATE


LEGEND
Main Channel
Secondary Channel
Abandoned Channel
Gaging Stations
Reference Points
Miles Below Head of Atchafalaya River
INDEX MAP
LOUISIANA
ATCHAFALAYA SHEET
5 Miles
10 Kilometers
PLATE 10
A
B
C
D
E
H
I
J
K
G-7
G-8
G-16
G-120
G-119
G-100
G-12
G-11
G-13
G-14
G-15
G-19
G-40
G-50
G-60
G-75
G-85
G-90
MORGAN CITY

Location Map-
Stage Profiles

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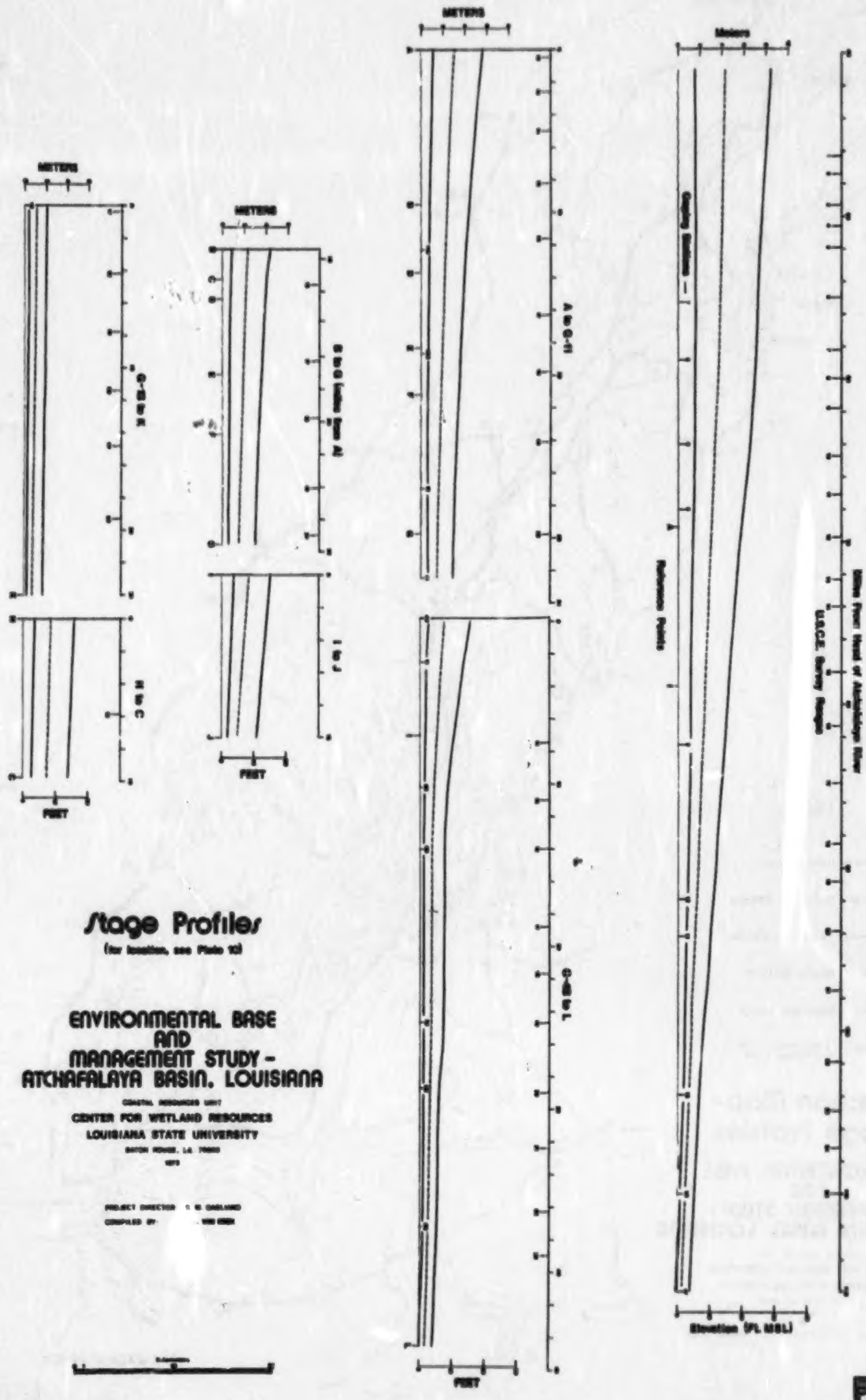

Stage Profiles

(for location, see Plate 10)

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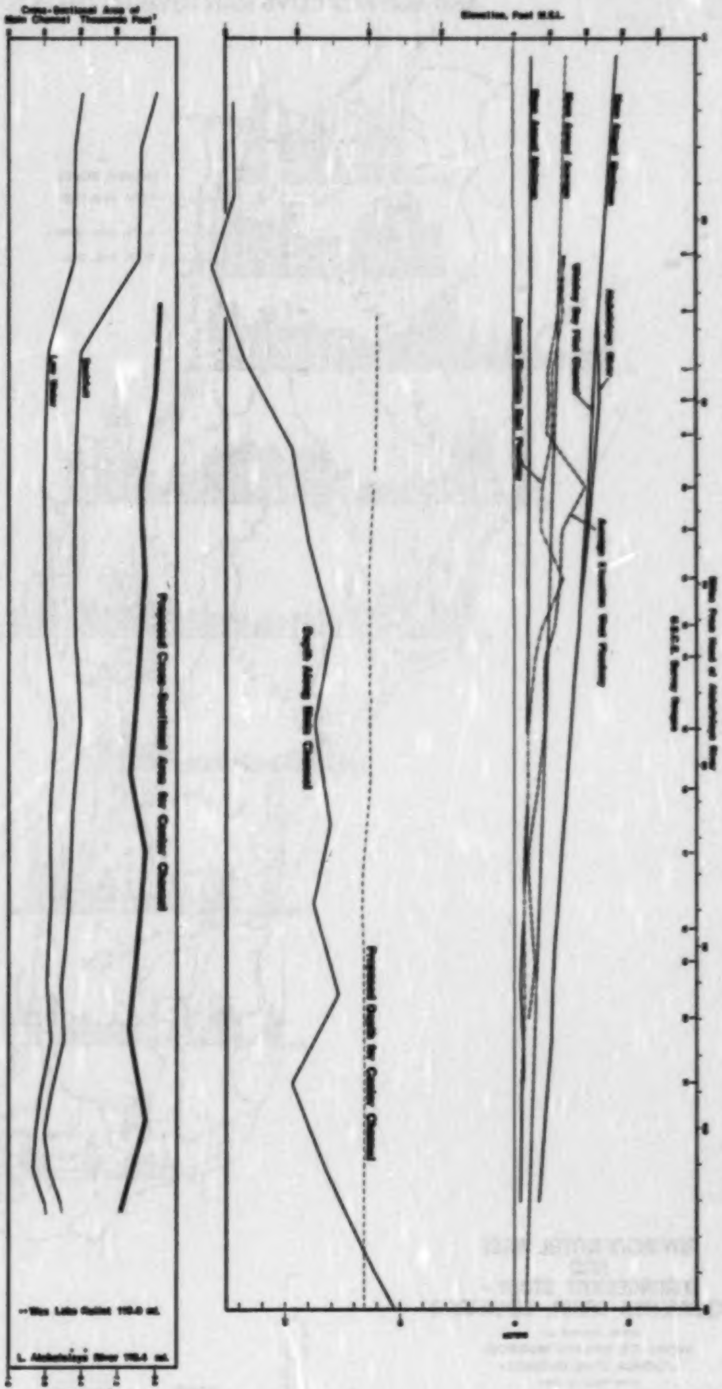
COMPILED BY [illegible]

PLATE 11

Basin Slope, Channel Profile and Cross Section

(for location, see Plate [illegible])



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[illegible]

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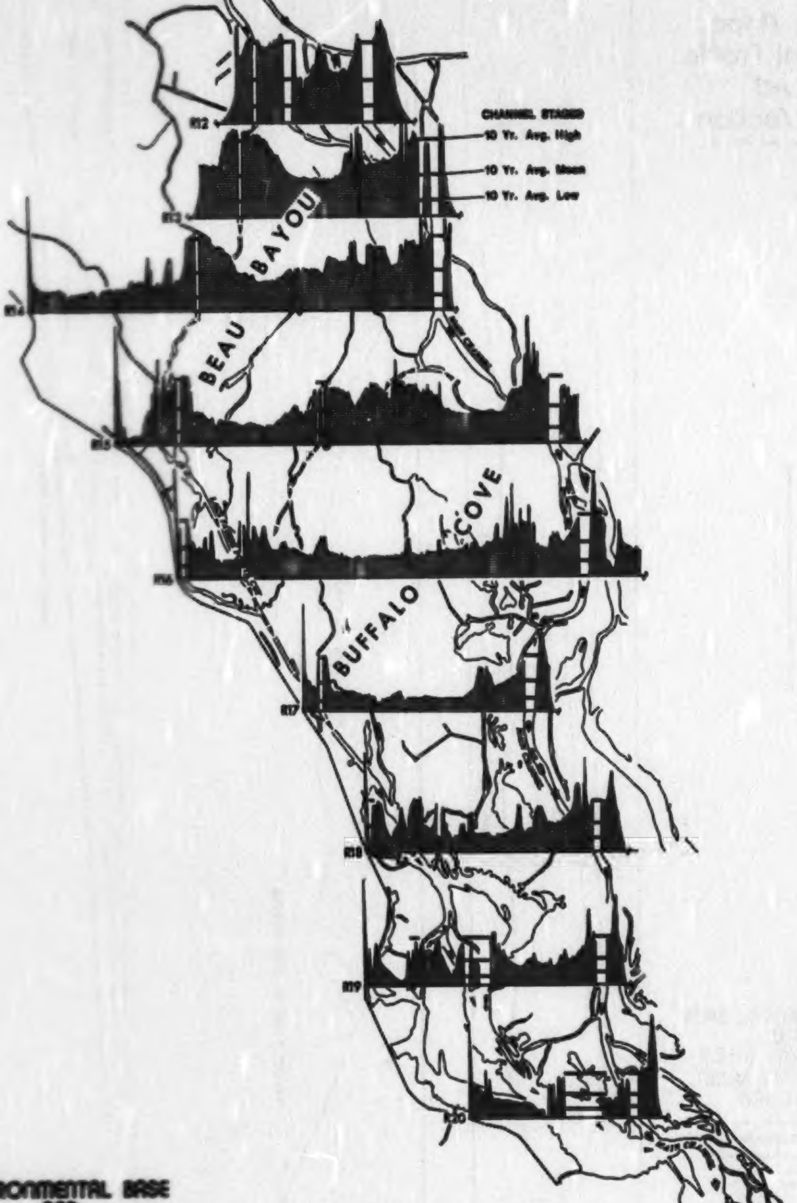
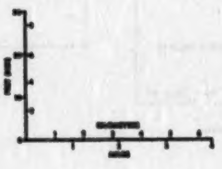
PLATE
[illegible]

TOPOGRAPHY ALONG U. S. C. E. SURVEY RANGES IN BEAU BAYOU AND BUFFALO COVE MANAGEMENT UNITS


R12
CHANNEL STAGES
10 Yr. Avg. High
10 Yr. Avg. Mean
10 Yr. Avg. Low
R13
R14
BEAU
BAYOU
R15
R16
COVE
BUFFALO
R17
R18
R19
R20



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AND
MANAGEMENT STUDY -
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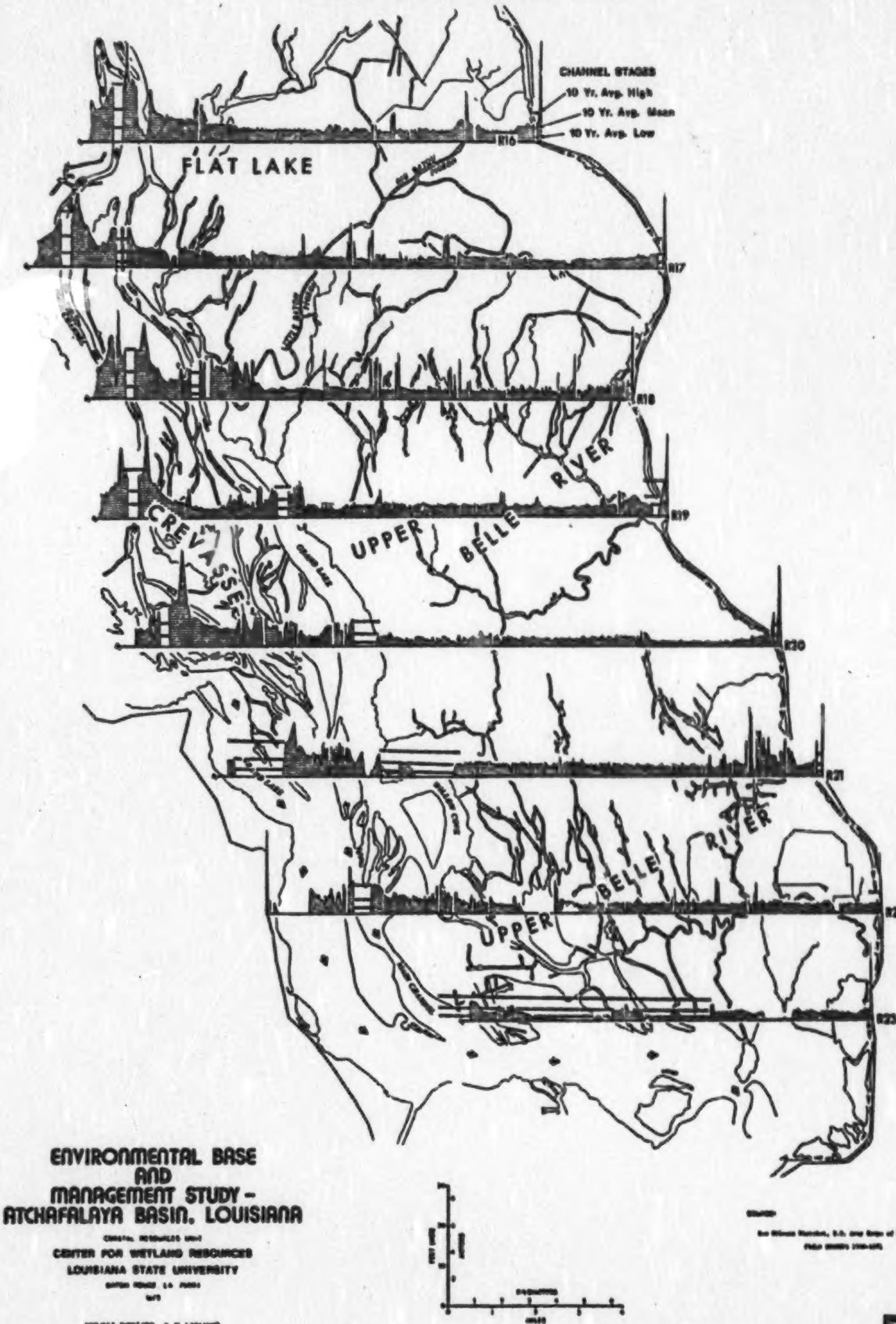
PLATE
18

TOPOGRAPHY ALONG U. S. C. E. SURVEY RANGES IN UPPER BELLE RIVER AND CREVASSE MANAGEMENT UNITS


CHANNEL STAGES
10 Yr. Avg. High
10 Yr. Avg. Mean
10 Yr. Avg. Low
R16
FLAT LAKE
R17
R18
RIVER
R19
CREVASSE
UPPER
BELLE
R20
R21
RIVER
BELLE
UPPER
R22
R23
MILES

ENVIRONMENTAL BASE AND MANAGEMENT STUDY – ATCHAFALAYA BASIN, LOUISIANA

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PLATE 14